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Abstract

This is a report of a study of national needs for computer based information systems in higher education. The study was limited to 5 problem areas that might best be solved through more central and cooperative efforts among institutions--administration, resource sharing, instruction, information science research, and libraries. Part I describes the study, termed Project ISE, and the actions recommended. It was conducted through the production of working papers covering the 5 areas, and subsequent meetings on over 80 campuses to discuss the papers with institutional officials. The results showed that 2 areas--administration and resource sharing--are in critical need of nation-wide, computer based information systems. The major recommendation calls for immediate establishment of a non-profit Institute for Information Systems in Higher Education to undertake programs in these 2 areas. Recommendations are also made for further study in the other areas. Part II contains the final versions of the working papers entitled: "Administrative Information Systems," "The Computer in Instruction," "Information System Resource Sharing," "Research in the Information Sciences," and "The Computer in the Library." The findings and recommendations presented in Part I are treated in great detail in Part II. (DS)

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Feasibility Study and Recommended Plan

for

Establishing an Institute for Information Systems in Higher Education

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prepared for

National Science Foundation

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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HE 001 188

Associated Universities, Inc.
Washington, D.C.

June 1969

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PROJECT ISE

STUDY REPORT

INFORMATION SYSTEMS IN HIGHER EDUCATION

prepared for

THE NATIONAL SCIENCE FOUNDATION

by

Associated Universities, Inc.
Washington, D.C.

1 June 1969

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PREFACE

For twenty years we have witnessed remarkable progress in understanding the nature of information and how it can be processed. The computer has been at the very center of this development. Those who became intimate with the computer -- in universities, in government, in industry -- achieved a new level of competence. The sheer bulk of information that could be handled and the complexity of the problems which could be solved influenced enormously the productivity and contributions of those having effective access to computer based information systems.

Nevertheless, today the computer still remains remote, physically and intellectually, from the daily lives of most people.

During the next twenty years computer based information systems will reach deeply into all aspects of society. It will be an era of sharply reduced costs, greatly improved ease of physical access, and much simpler communication modes between users and the computer. Since the computer is a machine for amplifying the power of man's intellect, its widespread availability will have particularly deep implications for higher education. Without question, computer based information systems fundamentally will change the content and processes of learning and research.

To date relatively few students in higher education have had exposure to the computer. Bringing similar advantages to a large percentage of all students -- undergraduates, graduates, and post-doctoral scholars -- is an immediate and difficult task. Much more difficult, however, will be the initiation of those steps necessary to achieve full potential of the computer in all aspects of the learning process. This undertaking will be one of great complexity since it involves an elaborate information system, including internal supervisory and user software as well as powerful computer hardware. The task is further complicated by the varied nature and ability of the user -- from the advanced worker in computer science to the freshman in economics, each working in an environment devoted to stimulate learning but in which little is known of how learning takes place.

Closely related to campus instruction and research is the administration of institutions of higher education. Here the problem centers on more effective use of campus resources -- on the best possible deployment of faculty, facilities and dollars to achieve economical, high quality education. The need for well designed and operated information systems to support decision making at all organizational levels on the campus is urgent.

A number of colleges and universities are doing work important to the needed developments suggested above. Such effort by individual institutions must be continued at increasing levels and with careful avoidance of needless duplication.

There exist, however, important problems requiring solutions which must be implemented, not on just one campus, but nationwide by many of the 2,300 institutions of higher learning. Dealing with many of these problems will require long-range and large-scale efforts. Project ISE has concerned itself with these more sizable issues.

This project, of one year's duration, has profited from consultation with many people in higher education and in the computer sciences community. The Advisory Committee, in particular, devoted many hours of spirited effort. Associated Universities, Inc. rendered valuable services as sponsor and host for the staff. The National Science Foundation, in cooperation with the U.S. Office of Education, provided the funding. Recognition must also be given to Charles Blair, the Associate Director of Project ISE, for his skilled and thoughtful contributions to all of the major issues addressed; to Lloyd Slater, Assistant to the President of AUI, whose great interest in the project and writing talents gave expression to much of the final report; to Mrs. Shirley Hamilton, who not only typed the final report manuscript, but contributed heavily to the coordination of project activities from the very beginning; and to Mrs. Lois Chew, who edited the final report.

Finally, I acknowledge gratefully the contributions made by the Chairman of the Advisory Committee, Dr. T. Keith Glennan, who was primarily responsible for the launching of this project and has served as a "prime mover" throughout. Both Dr. Glennan's and my own interest and concern for the problems addressed in this study have grown out of our shared experiences in higher education over much of the past twelve years -- he as President and I as Provost of Case Institute of Technology.

While much of the credit for what may prove of value belongs to others, I must, as Director of the project, assume full responsibility for errors, for omissions, and for treading in certain problem areas where the footing is soft and the direction to move is unclear.

John A Hrones

John A. Hrones
Director, Project ISE

Provost for Science and Technology
Case Western Reserve University

Washington, D. C.
4 April 1969

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SUMMARY STATEMENT

This report is of a study of national needs for computer based information systems in higher education and offers specific recommendations for a program of actions to meet these needs. The study was limited to those large-scale and long-range problem areas which might best be solved through more central and cooperative effort between institutions.

The report is developed into two major parts:

PART 1 ... is a relatively terse description of the complete study; how it was made, what its findings are, and the actions that are recommended.

PART 2 ... deals more extensively with five major problem areas in the application of computers in higher education -- in administration, resource sharing, instruction, research and the library. It is presented in the form of "working papers" which were developed, shaped, and reshaped in the course of the study. Many of the findings and recommendations presented in PART 1 are more exhaustively treated in PART 2.

Findings of the Study

The study determined that two areas -- administration and resource sharing -- are in critical need of immediate and major research and development effort which should be national in character. Other important areas -- in instruction, the library, and in research in computer science -- also were found to require important effort, but the actions necessary are clearly less well defined than those for administration and resource sharing.

Recommendations

The recommendation for immediate action is:

> Establishing a non-profit Institute for Information Systems in Higher Education to undertake immediately programs in administrative systems and in resource sharing among many institutions.

Recommendations for further study:

- Inaugurating a feasibility study for design and implementation of a regional unified library automation system.
- Organizing an inter-institutional facility for study of large-scale and long-range research projects in the information and computing sciences in the near future.
- Undertaking a large-scale effort to establish economical use of the computer in instruction; to be organized and launched within the next decade.

Chapter I

CONDUCT OF THE STUDY

Preliminaries

In the spring and summer of 1966, Dr. T. Keith Glennan, newly appointed President of Associated Universities, Inc., set out to visit the nine AUI sponsoring universities[1/] to identify and discuss problems in higher education which might possibly be solved best through inter-institutional cooperation and a national laboratory type effort. In almost all visits, discussions turned to the use of the computer on campus and to the profound effects computer based information systems are expected to have on all aspects of higher education. Later visits to other campuses and with many educators brought out further evidence of a growing understanding of the importance of this development. A pattern of general concern appeared to be emerging: despite burgeoning costs, how to extend as quickly as possible the advantages of computer technology to as many campuses and students as possible. How to do this effectively and economically is a national problem of great significance which, it would seem, might logically be approached through some kind of central and cooperative effort.

During the next year, encouraged by the AUI Board of Trustees, Dr. Glennan continued to explore the problem and to make plans for its review on a broader, national basis. In June 1967, he assembled a small group[2/] to formulate plans and objectives for the survey, which was carried out during the summer by Dr. Levien and Dr. Spinrad. By September 1967, a report of findings had béen prepared entitled "Planning Document for Establishing and Operating a National Institute for University Information Systems". This document brought into focus those areas of higher education most amenable to computer usage and suggested the structure and functions of a national institute "generally applied in character and with intimate academic participation, which could point toward the perfection of software systems to facilitate efficient and imaginative use of computing technology on our campuses".

[1/] Columbia Univ., Cornell Univ., Harvard Univ., Johns Hopkins Univ., Massachusetts Institute of Technology, Princeton Univ., Univ. of Pennsylvania, Univ. of Rochester, Yale Univ.

[2/] Dr. Ralph S. Halford, Columbia Univ.; Dr. John A. Hrones, Case Western Reserve Univ.; Dr. Kenneth M. King, Columbia Univ.; Dr. Roger E. Levien, The RAND Corp.; Dr. Richard G. Mills, M.I.T.; Dr. Philip M. Morse, M.I.T.; Dr. Robert J. Spinrad, Brookhaven National Laboratory.

Organization of Project ISE

The findings of this preliminary study were the basis for a proposal to establish "a study of the need for and character of an institute devoted to research and development of information systems to help achieve the rich potential of the computer and computer sciences in colleges and universities of the nation. The study will investigate how such an institute might further inter-institutional efforts to develop software systems which could improve and extend the utilization of computers on campus. Its objectives are as follows:

1. It will examine the important areas of interest which would serve as initial program areas for research and development in the institute.
2. It will validate the need for such an institute through a substantial sampling of the national academic community.
3. It will further refine and sharpen the functional and organizational concept for the facility to more effectively serve the needs and specific interests of colleges and universities.
4. It will directly explore the realities of staffing, visiting appointments, and the undertaking of cooperative projects with interested schools.
5. It will ultimately prepare a plan for establishing and operating the institute, should its need and practicality be demonstrated by evidence developed in the study."

The National Science Foundation, in cooperation with the Office of Education, U.S. Department of H.E.W., awarded a grant of $150,000 (limited to $121,400 due to Revenue and Expenditure Control Act of 1968) to establish Project ISE for the duration of approximately one year. The project was inaugurated on 1 April 1968 when Dr. John A. Hrones, on leave from his position as Provost for Science and Technology at Case Western Reserve University, became Director for Project ISE. Mr. Charles R. Blair, on leave from the National Security Agency where he is Chief of the Information Processing Research Division, became Associate Director. By June 1968 staffing was completed.

A twenty-seven member Advisory Committee was established with Dr. Glennan as Chairman.[3/] Nine members of this committee, also chaired by Dr. Glennan, formed the Steering Committee for Project ISE. The AUI Board appointed a six member Trustees' Review Committee under the Chairmanship of Dr. Carl C. Chambers, Vice President for Engineering Affairs at the University of Pennsylvania, to evaluate the conduct and findings of the study and report its observations to the AUI Board.

Activities

To pursue the stated Project ISE objectives, the staff undertook the following functional sequence of activities:

A. Gathering information and producing working papers to identify possible specific actions which might be taken in critical problem areas. These include administration, resource sharing, instruction, research, and the library.

B. Testing the validity of findings and the viability of suggested actions through individual discussions, seminars, and workshops on campuses in various parts of the nation.

C. Outlining desired long-range courses of action through a proposal of a more specific plan for near-future action.

D. Convening periodic meetings of the Project ISE Steering and Advisory Committees for review and advice on the conduct of the study.

A. Working Papers

The final versions of the five working papers produced in Project ISE make up Part 2 of this report. Three of the areas, partially considered in the working papers -- administration, instruction and research -- cover almost all operations of colleges and universities. A fourth -- the library -- is perhaps the classic example of a very large and complex information system which is of central importance to all education. The fifth --

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[3/] A list of the Advisory Committee members appears in the Addendum to Part 1.

resource sharing -- is a preliminary step in the attempt to solve, economically, some of the problems existing in the other areas.

It must be stressed, however, that these working papers are not meant to be exhaustive state-of-the-art reports; neither the time available nor the size of the Project ISE staff permitted such an effort. In fact, in all of these areas (with the possible exception of resource sharing), survey literature is already voluminous. Rather, these working papers are an attempt to put forth a course of action, predictably on a national scale, which will lead to the solution of certain major problems in each area. Each working paper thus materialized during the life of the project and was modified by findings in the field as well as in the literature. Each was subjected to critical review by the project's Steering or Advisory Committee as well as by interested people in the academic community. And each, in its final form, led to the recommendations which are put forth by this study.

It must be emphasized that these working papers, as their description implies, were for internal project use. Nevertheless it has been thought useful to include them in their present state to indicate the nature of the problems addressed.

Discussions, Seminars, Workshops

A serious effort was made to understand the problem areas under study through visits to campuses and to test, in seminars and workshops, many of the action-oriented ideas developed in Project ISE.4/ In brief summary, these field activities included:

Personal Contacts...Approximately 225 persons in over eighty institutions of higher learning were consulted and informed of the objectives of Project ISE. Non-academic organizations (industry, government, associations) were also consulted and inputs from these sources are included in the various working papers. A memorandum report on each of these discussions is on file.

4/ A list of personal contacts, seminar agenda and attendees, and recommendation/conclusions of the workshops are included in the Addendum to Part 1.

New England Regional Seminar...To help identify the problems and to benefit from the counsel and views of college and university officials, Project ISE invited representatives of 63 institutions in the New England area to a one-day seminar at Wellesley College. Following a morning session which outlined the concepts under study and the objectives being pursued, afternoon group discussions were undertaken in the areas of resource sharing, research and instruction, and administrative information systems.

Workshop on Humanities...Humanists from eight different institutions gathered at Queens College of the City University of New York for a one-day discussion of the potential role of information systems in the humanities and the role of a possible national center or institute with regard to humanities research.

Workshop on Instruction...Seven leading people in the field of computer assisted instruction met with Project ISE staff at Stanford University in Palo Alto, California, for two days to develop recommendations for national efforts and objectives.

Proposal

As exploration into the five principal areas of information systems in higher education proceeded, certain ideas developed for problem solving actions which could be carried out under the aegis of a centrally organized national effort or institute. These ideas, later expressed in more detail in the working papers, were then shaped into the form of a proposal which was submitted to the Steering and Advisory Committees, and others, for review. This proposal calls for the establishment of two related programs: 5/

An Administrative Systems Program...A research and development activity was outlined to study the educational institution as an operating input/output system and to develop needed techniques and procedures leading to design and implementation of full-scale administrative information systems adaptable to the individual needs of many institutions of higher learning. Major emphasis

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5/ These two programs are the dominant elements of an implementation proposal entitled "A Proposal for Establishing an Institute for Information Systems in Higher Education" which has been prepared by the staff of Project ISE. The concept of this proposed Institute is stated in the major recommendation of Chapter III. A summary of the proposal is included as the last item in the Addendum to PART 1.

of the program is on field-tested operating systems with strong participation by visitors and temporary staff from interested colleges and universities.

A Regional Resource Sharing Program...The plan is to work with approximately 200 institutions of higher learning located in a concentrated geographical area toward the development of methods for the large-scale sharing of information system resources -- equipment, personnel, software, information science educational programs. One possible design of such an operating system which has been examined for feasibility is discussed in Chapter V.

Plans for other important large-scale undertakings are discussed in working papers on the computer in instruction, research, and the library in the information sciences.

D. Meetings

Advice and counsel were extended to the study staff by the three committees formed specifically to lend assistance in pursuing the project objectives.

Steering Committee...Nine members of the Advisory Committee whose major purpose is to review Project ISE working papers, recommendations and proposals, before they are submitted to the Advisory Committee for consideration.

Advisory Committee...A nationally representative group consisting of twenty-seven members selected from the educational community as well as certain user areas whose role is to consider project findings and test recommendations in the light of national interests and needs.

AUI Trustees' Review Committee...A group of six AUI Trustees whose purpose is to evaluate the conduct and findings of the study and report its observations to the AUI Board.

A brief synopsis of committee meetings follows:

21 March 1968...Prior to commencement of Project ISE the Steering Committee met to propose names for Advisory Committee, suggest staff personnel recruitment, and to advise on initial steps taken by the project.

22 May 1968...The initial meeting of the Advisory Committee to discuss the mission of the project, the role of the Committee, and the design of the study. A brief meeting of the Steering Committee followed to review results of this first meeting.

1 July 1968...Steering Committee meeting, hosted by Bell Telephone Laboratories in Murray Hill, New Jersey, to review agenda items of forthcoming Advisory Committee meeting; The Computer in Instruction and Information Systems Resource Sharing.

13 September 1968...The second meeting of the Advisory Committee to consider a plan for a regional resource sharing system proposed by the project staff and to discuss the first draft working paper on The Computer in Instruction. A brief meeting of the Steering Committee followed to discuss further regional resource sharing and future plans for seminars and workshops.

18 November 1968...A meeting of the Steering Committee to discuss and review the first draft of document: "Basis for a Proposal for Establishing an Institute for Information Systems in Higher Education."

16 December 1968...The third meeting of the Advisory Committee to consider the second draft of "Basis for a Proposal for Establishing an Institute for Information Systems in Higher Education" with specific emphasis on a program in administrative systems.

25 March 1969...A meeting of the Steering Committee to review and discuss recommendations to be presented in the Final Report of Project ISE and to evaluate the first draft of a proposal to establish an Institute for Information Systems in Higher Education (IISHE).

May 1969...An Advisory Committee meeting to review the Final Report of Project ISE.

Chapter II

FINDINGS

Limits of Study Area

Beginning in late May 1968, Project ISE attempted to identify certain steps which might be taken by higher education, perhaps on a cooperative or inter-institutional basis, to extend the use of computer based information systems more generally and effectively throughout the educational process. Because of the breadth and complexity of the study area, the project, in its effort to propose problem solving actions, operated within the following constraints:

1. It was primarily concerned with identifying problem areas having long-range significance to many educational institutions which differ in type, size, nature of curriculum offerings, and in ability to make use of computers; and

2. It dealt only with those problems...

   a. to which solutions are required that can and will be broadly applied in post-secondary institutions across the nation;

   b. that a single college or university or small group of such institutions cannot or does not desire to undertake;

   c. where the cost of the solution or nature of the problem requires a strong inter-institutional effort on a national basis;

   d. where the skilled people needed for solutions -- particularly in smaller institutions -- could best be developed initially through a central training effort.

Even operating within these limits, it was exceedingly difficult for the study to confine itself to a series of manageable topics. One has only to spend a few hours touring any of our major universities to realize how extensively the computer and information system concepts are starting to enter into every aspect of campus life. Aside from their established, substantial role in research in engineering and the physical sciences and in institutional bookkeeping, interesting experiments are being conducted with computers in teaching, in library use and management, in creating new forms of effective communication with surrounding institutions, and in establishing useful new approaches to research and instruction in some scholarly fields heretofore considered unassailably "non-quantifiable". However, if one spends some time with people involved in almost any of these promising new areas for computers in higher education, even at our most endowed universities, a sobering realization of the complexity and cost of further development emerges. Yet, it is essential that these promising results be made available in usable form to all of the higher education community.

As indicated in Chapter I, the project staff developed its findings in a series of working papers, which were subject to a process of review and revision over a period of months. While these papers present a broader discussion of each issue, a concise summary is necessary as a prelude to the study recommendations which follow in Chapter III.

Areas of National Concern

Project ISE, interested broadly in the more effective use of information systems in many institutions, subdivided its task into five principal problem areas which clearly seem to be of national concern. A brief summary of the situation and apparent need in each of these problem areas follows:

1. Administration...The word "administration" is used in its broadest sense and includes the following actions directed at providing the best possible learning environment:

    - policy and program planning at all levels,
    - implementation of adopted policies and programs, and
    - improved day to day operational procedures.

    It is estimated that higher education will enroll approximately ten million students in 1979-80 with annual operating costs of about $30 billion. Thus, a doubling in the resources presently available to higher education will be required. Individual colleges and universities are already facing increased difficulty in financing their growing operations. Simultaneously, there is a rapidly growing need to appraise the probable neartime and long-range influence of proposed changes in educational programs and organizational structure on the quality and cost effectiveness of institutions of higher learning.

An institution of higher education is a complicated system, constantly changing as the fields of knowledge grow, as understanding of the process of learning grows, and as society itself changes. Each institution has limited resources of manpower, facilities and funds, which can and must be used effectively in a wide variety of ways. Each institution should be in a position to make decisions at all levels and in all areas to use these resources in offering the best possible education to each of its students with the dollars available.

Thus, in its broadest context, a well designed and implemented administrative information system is needed to provide every teacher with current information which helps realize a better learning situation for each student. The information system also must enable the faculty member to reduce to a minimum the time he spends on paper work. It must provide current information in an easily usable form to those charged with administering departments, schools and research projects in order to free them of routine and permit more time for the educational development aspects of their work. It must provide the president and his staff with access to a wide variety of factual data regarding people, physical plant, equipment, courses, research projects and proposed undertakings to help them develop strong planning efforts. And it must make available pertinent information on the consequence of courses of action to facilitate important educational and management decisions.

Few institutions of higher learning are able, on their own, to reach a position to carry on the important planning and implementation activities referred to above. Each institution is facing increasing difficulty in just meeting its day to day operational requirements. Most of the 2,300 institutions of higher learning do not have the resources in money or talent to develop and use an effective planning activity supported by an appropriate information system. They need help.

A central effort of critical size, closely tied to the higher educational community, is needed for fundamental studies of individual colleges and universities as systems and to design, develop, and implement appropriate computer based information systems which support decision making at all administrative levels. Such a central effort would enable a talented group of people (former college and university administrators, systems analysts, information and computing scientists) to concentrate on the development and implementation of systems in many institutions of higher learning. Unlike individual institutions, such a central effort would not be hindered by day to day operational crises. Its existence would eliminate many duplicative and abortive efforts. It would provide a center through which important work in administrative systems might be implemented on many campuses and offer programs to train college and university people to use the systems developed. Thus, a central effort devoted to the design and implementation of administrative systems for higher education would be the most effective way to use scarce resources. See Chapter IV for a more detailed discussion of information systems in administration.

2. Resource Sharing...The extension of computer based information systems into all areas of the educational process faces two natural inhibitors: the problems of limited funds and the shortage of competent people. The large computers and necessary auxiliary equipment are often too costly for most campuses. The special knowledge and skill required for developing and applying software are in short supply -- and expected to be so for many years. Large institutions that have invested in sophisticated computers to meet the needs of advanced groups on their campuses often find this expensive equipment is neither fully loaded nor efficiently used. Smaller campuses often need access to large machines that are clearly beyond their means.

   Both the National Science Foundation and the U.S. Office of Education, well aware of this growing financial burden, have encouraged projects where groups of institutions have attempted to pool or share resources to gain more effective use of computers. While these projects are expected to yield immediate benefits to participating institutions, their emphasis is mainly on the extension of computing power to smaller institutions through clustering about a large, central institution.

   A central effort involving many institutions over a sizable geographic region is needed to establish a sound basis and to develop techniques for resource sharing systems that could serve most of the 2,300 institutions of higher learning in the near future. See Chapter V for details on a proposed regional resource sharing system.

3. Instruction...The central purpose of colleges and universities is to provide an environment for learning. Advances in the information and computing sciences can be immensely important in understanding and improving the learning process, and research in this area is accelerating at a rapid rate. The results suggest that computer based systems can be of great assistance in instruction at all levels. The potential usefulness of the computer in instruction and learning is barely exploited.

   At present some sixty million students are in elementary, secondary, and higher education in this country. Each year more students complete high school, go to college, and enter graduate schools. The population is growing. Society, confronted with technological and social change, needs better educated people. Yet, with rising demands for education, the supply of qualified teachers is severely limited. Economical use of computers for instruction may make it possible to meet the demand for quality education and, at the same time, provide greater attention to individuals.

   There is an important and urgent need to complement present activities with a large-scale effort aimed at developing broadly applicable components with greatly improved cost/benefit ratios. See Chapter VI for a more comprehensive analysis of the potential of computer based systems in instruction.

4. Research...Research in the information sciences has a different meaning and a different payoff than does research in many other professional areas. Results have very broad implications -- for all professional fields are highly dependent upon the availability and effective use of information systems. Exciting, new and relevant work in the humanities, the arts, the physical and life sciences, engineering, management, medicine, etc., is highly dependent upon progress in the information sciences. Because of this fact, valuable research in the information sciences is carried on in other professional fields. Nevertheless, the focus of front running research is in the small but growing group of professionals who regard themselves as information or computer scientists.

   The character of computer research differs with respect to scope, kind, and support required. Important contributions can be made by one man on a small college campus -- but this is unusual.

More often, outstanding work is carried on by a professor at a relatively large university working with a number of graduate students and, sometimes, other professors or a few highly selected undergraduate students. Usually the problems addressed are not only very important but are ones where the chance of visible progress by a small group in a limited time is good. Research by industrial organizations is necessarily closely tied to developments with neartime profit potential. It is clear that each of these sources for creative work will continue to grow in strength and productivity.

Important information science problems exist which neither institutions of higher learning nor industrial organizations have incentive to undertake. Such problems are characterized by one or more of the following conditions:

- the time required for substantial progress is long;
- a large, full time supporting staff is necessary;
- very large-scale, flexible equipment must be dedicated exclusively to research;
- the activity must have extensive testing.

An example is the design of an integrated system incorporating hardware, system and applications software for optimum use by educational institutions.

The establishment of environments for such advanced research is important to the future of computing science and to the growing world of users from all disciplines. The lessons of the past indicate this is too large, too long-range, too expensive a task for any single university to undertake. In addition, results of such efforts from industrial organizations may not be made generally available. See Chapter VII for a review of some of the contemporary problems in computer science and a suggested approach to their solution.

5. The Library...College and university libraries are finding it more and more difficult to maintain the present level of service because of expanding publication. At the same time, they are being called upon to provide more advanced services. As a result, library costs are going up more rapidly than the already impressive growth in acquisitions. Computer based systems are expected to help solve these problems.

Many factors, however, make it extremely unlikely that individual libraries will develop their own automated systems and suggest a central effort in this area. One difficulty is the growing scarcity of adequately trained people compounded by great pressures for the provision of immediate library service. Further, the costs and complexities of pioneering in computer usage are out of the reach of most libraries. Even if each library did undertake automation, however, full use of the world's total published information must involve multi-institutional effort.

Substantial work is needed to improve existing procedures through the use of computer based systems while designing and constructing new systems to provide fundamentally different library services for the future. See Chapter VIII for a discussion of a proposed regional, unified library automation system which could be expanded into a national system.

Paths to Solutions

As suggested, all of the aforementioned areas of national concern, in extending use of information systems in higher education, have one thing in common: they involve long-range problems, complex in nature, which require important new and continuing efforts for their solution. At the present time most of the work on new applications of computer based systems in higher education is supported by the government and by private foundations. Clearly, these are the most likely sources for the markedly increased support which will be necessary in the years ahead. Project ISE identified the major problem areas and suggested the kinds of actions needed to effect solutions. The question it next asked was: How might these actions best be undertaken? Six possibilities were identified:

1. Substantial increases in funding could be directed into all areas, with an increasing but limited number of institutions competing for funds in the traditional manner;

2. Consortia or groups of institutions could be formed to accept special funding directed toward specific problem areas;

3. Regional and national associations could undertake projects leading toward solutions of national problems;

4. Industrial organizations could help answer the problems of information systems in higher education through profitable market development and service activities;

5. National centers or laboratories could be established, closely tied to the higher education community, to work on problems requiring sizable groups of skilled people and large resources;

6. A federal agency could be established to develop information systems in higher education through in-house and contract R&D programs.

It was apparent to Project ISE that the first two paths, which already exist and are producing important results, must continue to be open and heavily used with the support of substantial additional funding. In certain areas, such as the use of computers in instruction and research in computer science, continued and increased funding of efforts by highly creative people in teaching institutions is essential, since developments in each of these areas so closely relate to the higher education process itself. Clearly, most innovations in the use of computers for instruction can best be born in an environment which includes classrooms and students as well as gifted engineers and scientists. Also, universities must attract and hold advanced researchers in computer science if our graduate education system is to produce people who work in this field. Still it must be recognized that progress of this kind depends in large measure on the participation of a very small number of institutions with the people and resources necessary to undertake creative work related to the computer sciences.

During the past few years, several important national and regional associations have formed which are primarily concerned with better use of computers in higher education. EDUCOM, Interuniversity Communications Council, a national endeavor involving representatives from approximately 100 institutions, is undertaking study projects aimed mainly at better movement of information between institutions. It does its work with a small staff augmented by volunteer task forces. Regional organizations include: SREB, Southern Regional Education Board; WICHE, Western Interstate Commission for Higher Education, principally devoted to cooperative effort on administrative systems in certain institutions of higher learning in the far west; NERComP, New England Regional Computing Program, which is attempting to share available computer power in the northeast region of the country among sixty or more schools.

Some technical associations (e.g., Association for Computing Machinery, Association for Educational Data Systems, Institute for Electrical and Electronics Engineering) have created special membership groups to study and report on developments in computing in higher education. All of these organizations, private, regional and technical, serve the highly important functions of improving communication among people who use computers on campus and of involving increasing numbers of people at the working level in regional and national problems.

The computing industry and related for-profit service industries have encouraged the use of computers on campus and done much to assist individual institutions in routine applications. There seems little likelihood, however, that industry will find the necessary incentive to undertake the major research and development efforts suggested by the problems identified by Project ISE. At the present time, those able to contribute significantly in this area -- the few very large machine manufacturers -- find that the field of higher education is only a modest fraction of their total market and they are obliged to treat it accordingly. Those smaller firms, which have been established to deal primarily with education, lack the resources for very large, complex and long-range tasks.

It was the conclusion of the study that while all of the possible paths listed above must be supported in increasing measure, substantial progress in certain of the areas of concern will best proceed through path 5, the formation of national centers, dedicated to the principal problem area, which would work closely with people and institutions of higher education. Such a center would bring together the critical mix of people -- professional, technical, operational and supporting -- required to solve complex, long-range problems as well as successfully implement their solutions on collaborating campuses. The need for such coordinated central action is particularly acute in the administration and resource sharing areas, where it appears possible to bring benefits rapidly to many of the nation's 2,300 institutions of higher learning.

Path 6, the formation of a federal agency to achieve the progress desired, was not viewed as a desirable option by Project ISE. The concept of non-governmental national centers or laboratories, established as needed and working in concert with existing institutions, appears most likely to meet effectively the needs as they can be visualized over the next decade. However, should this show signs of being inadequate, the importance and urgency of the problem certainly suggest the implementation of federal programs similar to those undertaken for exploring space or utilizing atomic energy. Most members of the academic community would prefer to avoid this solution.

Chapter III

RECOMMENDATIONS

Computer based information systems have such a broad influence in so many areas of higher education that a number of problem solving actions require national attention. A major consideration of the study, therefore, was to establish priorities for recommended actions -- particularly on the basis of timeliness, manageability, and prospects for funding. The levels of recommendation are:

> Immediate action on problems identified as most urgent by establishing a new, national center; and
>
> Further study of certain areas which, while dealing with subjects of major importance to higher education, require more investigation before actions are taken.

The Major Recommendation

Establishing a non-profit institute*, essentially national in character and closely tied to the higher education community through management and structure, was determined the most promising way to undertake certain of the activities recommended by Project ISE. Two activity areas were identified as essential tasks of the institute and an adequate reason for its immediate start:

> A program devoted to improving administrative information systems in higher education; and
>
> A program to develop an economical and effective mechanism for the sharing of information system resources among institutions of higher education.

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* "A Proposal for Establishing an Institute for Information Systems in Higher Education", 15 April 1969. Project ISE, Associated Universities, Inc., Washington, D.C. (A summary of the proposal is included as the last item in the Addendum to PART 1.)

The institute proposed has the following character and design:

Role

The institute will be devoted to continuing study of the national needs of the higher education community for more effective application of computer based information systems, and to the implementation of programs to help meet these needs. It will fulfill this role as follows:

> The Governing Board and top management staff will be drawn from the higher education community;
>
> The institute will...
>
> - undertake studies of problems of fundamental importance to many institutions which are too costly or complex to be solved by a single university or group of cooperating institutions. Initial activities will be in the areas of administrative systems and large-scale resource sharing.
> - assume the responsibility to help implement its results in a number of colleges and universities.
> - serve as a center where visiting faculty and administration people from colleges and universities can participate in its studies and training activities as well as join in programs of research and development.
> - have an active program in the field, including the installation and testing of prototype systems on participating campuses.

In summary, the role of the institute will be not only to recommend and develop, when required, broadly needed new techniques and systems, but to assure, through training, information dissemination and consulting services, that these are placed into successful operation in many and varied institutions of higher education. In fulfilling this role, the institute will have to be exceedingly flexible in outlook, adapting its mode of operations to the specific circumstances in each area it seeks to serve.

Rather than duplicate, it must build upon, complement, and encourage effort that is already underway in colleges and universities, in government and professional societies. A primary responsibility, therefore, will be to maintain close and vital relations with the higher education community, equipment manufacturers and potential funding sources, and the scope and nature of its operations will be influenced primarily by its dedication to that concept.

Structure

The institute will be an independent not-for-profit corporation, established by a founding group representing the national interest and coming largely from institutions of higher education. After incorporation, this founding group will be expanded into a Governing Board. A small executive group will form the initial core staff of the institute.

Scope

The institute will develop, to serve in its initial programs, a staff of about 160 people within five years. Because of the need to evaluate new developments as well as design and implement systems in the field, the staff mix will be exceptionally varied; it will include analysts, management and operational people as well as technical staff in the forefront of information systems design. To help assure use of techniques developed and increase competence in information systems at the campus level, the institute will involve active participation by large numbers of visitors from the academic community and substantial work in the field.

Location

The institute will be located in a community which is central to a region containing a large number of educational institutions and easily accessible by various modes of transportation. To retain its inter-institutional character, it will not be placed on the campus of any existing university or college. Nevertheless, the institute must exist in a campus-like atmosphere and should be relatively near a major, distinguished university, a well developed library, technical resources and computing power.

Initial Programs

As indicated above, the initial programs of the institute will be concerned with administrative information systems and resource sharing in higher education. Both of these problem areas are of immediate and grave concern to many educational institutions and are fundamental to further progress in the use of computer based systems on campus in instruction, research and the library. There are also a strong relationship and interaction between the two problem areas since it is anticipated that many of the institute's developments in administrative systems technique will have to be implemented on many campuses through resource sharing systems. A more detailed discussion of these two initial institute activities follows.

An Administrative Systems Program

It is recommended that a central inter-institutional effort be organized immediately to develop and implement use of improved information system techniques in the administration of colleges and universities. The goal of the program would be to develop a framework of information systems to support decision making and to help implement subsequent operations at all administrative levels. Such systems must be devised in close cooperation with a substantial number of colleges and universities. They must be installed and tested to insure flexibility to meet diverse institutional needs. The initial work should be directed at two and four year institutions of higher learning, with university applications following as soon as possible. It is believed that work at the college level, properly directed, will also be a foundation on which university applications can be developed.

The importance to the nation of the improved utilization of resources of higher education which should result from this program is sharply outlined by the fiscal facts. It is estimated that the total annual operating expenses of institutions of higher education in the year 1979-80 will be approximately $30 billion. Thus, improved planning, implementation of adopted plans, and improved operational procedures could produce savings of several billion dollars per year. Such savings may be realized in a number of ways -- improved quality of education, reductions in contemplated expenditure per student, the "avoidance of disaster". With respect to the latter, a well conceived model with appropriate analysis can assess the probable output, the costs and probable additional income associated with a proposed program over a period of years to avoid unforeseen fiscal crisis. For further discussion of this program, see Chapter IV.

A Resource Sharing Program

It is recommended that a central program, coordinated with the Administrative Systems Program, be organized immediately to develop methods and techniques for sharing information systems resources (equipment, software, manpower, programs) among many institutions. To produce usable results, the major task of the program should be to establish a prototype resource sharing system involving approximately 200 institutions in a densely concentrated geographical region. Experiences gained from such an operating system would provide useful design criteria for other regions of the nation to bring resource sharing eventually to over 2,000 existing institutions of higher education. The national network plans of ARPA and EDUCOM would help, and be aided by, this activity. For further discussion of this program, see Chapter V.

Secondary Recommendations

The following secondary recommendations are regarded as very important but, in contrast with the major recommendation of the study, which carries the highest priority rating and is supported by a separate formal proposal for action, require further study to determine the mechanisms best suited to achieve the results desired. Estimates of practicable objectives, schedules and costs are provided as appendices to the working papers supporting each of the secondary recommendations. Obviously, these estimates do not constitute a proposal; they are included to indicate the approximate costs in time and manpower of achieving certain worthwhile goals. More precise figures are best obtained from organizations which propose to implement the suggested systems.

Recommendation 1

A Regional Unified Library Automation System

It is recommended that further study be undertaken leading to the possible establishment of a regional, computer based, extensible library file system and union catalog in general accordance with the steps outlined in the feasibility study in Chapter VIII. Such a development, which would involve participation by libraries in about 200 institutions, could be the basis for expanding the service to a national system which could serve most institutions of higher learning. It is estimated that installation of such a system nationally would cost approximately $12 million expended over a period of about ten years. Upon completion, an average operating cost per student enrolled would be about $3.00 per year.

Recommendation 2

Research in the Information and Computing Sciences

It is recommended that the federal government substantially add to its support of research in the computer sciences. Much of this additional funding should be applied to increase the amount of research on the individual campuses. However, there exists a growing need for an environment, or environments, adapted to the conduct of large-scale and long-range research projects in the computer sciences. Such an environment should be one attractive and open to qualified researchers from all of the nation's colleges and universities. There must be available large and flexible equipment dedicated to advanced large-scale research in computer science. A number of configurations of such an inter-institutional operation are possible and further study, solely focused on this matter, is required. It is likely that annual operating costs of such an activity would be about $5 million with an initial capital equipment cost of $10 million or more.

A center for research in the information and computing sciences could contribute profoundly to many users of computers. Even engineers and physical scientists, who are already heavily involved in computing, expect "breakthroughs" in information systems techniques will lead them to more imaginative applications and accelerated progress. The most dramatic benefits, however, are expected in fields that are just beginning to apply computers; the life and social sciences, the humanities and the arts all abound with opportunities for exciting and productive new uses. Researchers from many areas would look to the center to stimulate advanced uses of computers in their fields of study. Although the resources of even a large center would be inadequate to serve most disciplines, some cooperative research could result in gains both in computing science and the selected applications areas.

Recommendation 3

Instructional Use of Computers

It is recommended that within the next decade a large-scale effort be launched to establish the use of the computer in instruction on an economically attractive basis. Emphasis needs to be placed on exploratory development leading to the construction and testing of prototype systems for the economical preparation and presentation of instructional materials. Related activities could include studies leading to better understanding of the learning process and a center for collecting, refining, extending and distributing course materials. For maximum effectiveness, the effort should be closely associated with several innovative educational institutions which participate actively in the necessary experimentation. The estimated annual budget for a single activity of this nature is approximately $2 million.

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Advisory Committee Meetings

May 22, 1968	Washington, D.C.
September 13, 1968	Washington, D.C.
December 16, 1968	Washington, D.C.

Steering Committee Meetings

March 21, 1968	Washington, D.C.
May 22, 1968	Washington, D.C.
July 1, 1968	Bell Telephone Laboratories, Inc. Murray Hill, New Jersey
September 13, 1968	Washington, D.C.
November 18, 1968	Washington, D.C.
March 25, 1969	Washington, D.C.

INFORMATION SYSTEMS IN EDUCATION

New England Regional Seminar

November 25, 1968

Recreation Building
Wellesley College
Wellesley, Massachusetts

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9:30 - 10:45	Plenary Session, NERComP Institutional Representatives

. . . .

9:30 - 10:45	President's Round-Table Dr. T. Keith Glennan

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AGENDA

Presiding -- Dr. Philip M. Morse

11:00 - 12:00	Presentation Dr. John A. Hrones
12:00 - 12:30	Question and Answer Period
12:45 - 1:45	Luncheon, Pomeroy Hall
2:00 - 4:00	Group Discussions

- I. Library and Administration
  Dr. Hrones, Chairman
- II. Resource Sharing
  Mr. Blair, Chairman
- III. Instruction and Research
  Dr. Morse, Chairman

Sponsored by Associated Universities, Inc.

WORKSHOP ON HUMANITIES

10 October 1968
Queens College
Flushing, New York

The general conclusion of the group was that humanities research is characterized by problems sufficiently peculiar to itself to make advisable a separation from parallel work in the social sciences, as there would be with researchers in library automation and computer assisted instruction, both of which fields will ultimately serve the practical needs of humanists and will benefit from advice on which needs they best can serve. But the best conditions for imaginative and valuable research in the humanities provide a minimum of structure and unnecessary external involvement. In such an atmosphere, it should be possible to promote research on the frontiers of current knowledge and to map out ever newer developments in software and hardware to assist in information storage and retrieval in the library, in the publication of scholarly aids by photo-composition, and the conversion of lengthy texts into machine-readable form.

The particular means by which these general ends would be reached depend on the establishment of text libraries in all the humanistic disciplines. In some, such as literature, the problems are relatively simple: the determination of adequate codes for data preparation and care in the preparation and storage of the materials. In others, like the visual arts, the very fundamental question of what to encode must be answered first. The Institute, by becoming the chief source of uniform and reliable texts, would establish standards to be followed elsewhere; the absence of such standards has been a major problem during the early years of computer humanities research, when isolated individuals innocently invented idiosyncratic and incompatible codes. The centralization of texts should also reduce some of the current confusion over a scholar's rights in a text he has personally made machine-readable. To supplement this library of texts, there should likewise be data banks (e.g., bibliographies), also available to researchers outside the Institute. The spectrum of services could be completed by a general clearinghouse for texts processed elsewhere, additional data, programs, and any other materials which could be exchanged among scholars. The Institute should be able to sponsor some projects which are not in the avant-garde but which cannot be done elsewhere for lack of personnel or equipment and which will stimulate other research once their results are available. Concordance might represent this type of project.

Other activities of benefit to the general commuity of humanists include the creation not only of special programs for humanities problems, but ever new user-oriented languages. These are among the materials which could be described in manuals and primers to be produced under the sponsorship of the Institute. No such works exist today for humanists, despite a growing interest and expressed need. Although created at the Institute, these works (as well as the publishable results of research conducted there) should be released through established channels; the members at the workshop felt that the Institute would achieve little good by becoming its own publisher. Instead, instruction could be offered through workshops, symposia, and summer institutes, all of which should be regular features. The circulation of permanent personnel between the Institute and the academic community at large would also constitute an educational service. Although there was general agreement on the importance of all these functions, the variety of emphases expressed reflected some polarization of thought. There was, on the one hand, the conception of a center primarily for advanced humanities research, in which computers might prove useful at some stage. To this was counterpoised the idea of an institute for the development of information science, of which humanities would be one division. The workshop felt that this fundamental distinction should be borne in mind as plans progress and hopefully be resolved within the context of the entire project.

The personnel of the humanities section of the Institute were conceived of as centering on a small cadre of resident researchers, whose tenure would be for relatively long periods. To that extent, this operation would constitute a "think tank". The core group would be supplemented by fellows who would come for briefer periods, on sabbatical leave, on summer vacation, or on a grant from some other source, their projects having been approved by the administration of the Institute. A special effort should be made to attract as researchers graduate students whose dissertations would benefit from a stay at the Institute and who would become foci of computer expertise at their future posts. All these scholars would benefit from interaction with a corps of programmers who had special humanities orientation, and whose training and concentration would enable them to respond creatively to the needs of the humanists rather than (as is often now the case) attempt to impose a scientistic technique on their projects. The software created by the conjunctive efforts of these workers could be used or adapted all over the country.

Because no meaningful humanities research can be conducted beyond easy access to major libraries, archives, and other repositories, the workshop was unanimous in its desire to see the Institute located in the suburbs of a major city, although distinctly unaffiliated with any university. Boston and New York were the two cities mentioned by name.

The session was characterized by enthusiasm at the prospect that the Institute might provide for the stimulating exchange of ideas, allow close collaboration among scholars, and particularly eliminate the ignorance, confusion, and solitude which hamper so much computer research in the humanities. The hope was expressed by one participant that with proper facilities, researchers might even begin to understand the fundamental processes of creativity, the point at which humanities research and psychology merge into a universal theory. All participants dedicated themselves to further work on behalf of the Institute, and to generating support among their colleagues. Their vision extended beyond the concrete advancement of many types of humanities research to benefits in the social sciences and the natural sciences, which can profit from techniques perfected by humanists. There was no exception to the firm belief that substantial and widespread good can come from the establishment of such a major research facility.

INFORMATION SYSTEMS
IN EDUCATION
PROJECT ISE

ASSOCIATED UNIVERSITIES, INC.
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WORKSHOP ON HUMANITIES
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Dr. Thomas J. Condon
American Council of Learned Societies

*Although absent, they contributed to workshop report/conclusions.

WORKSHOP ON INSTRUCTION

5-6 December 1968
Stanford University
Stanford, California

Recommendations

The working group distinguished, within interactive instructional uses of computers, (1) those in which the computer system modifies its behavior according to some measurement of the learner's behavior, so as to change the learner's behavior (e.g., so that he will learn), and (2) those in which the computer system does not modify its behavior based upon measurements of change of behavior in the learner. For example, many simulations and games belong to the second group, as do programs for manipulating formulae, for lens design, etc. These serve as an environment in which the learner can exhibit behavior, examine its consequences, and possibly learn, but the environment itself does not explicity change because of this learning. Most current CAI belongs to the first class, although at the "simple" end of any scale of program or task complexity. Conceptually, instructional environments could be both complex and reactive to measurements of learning.

Within this definition of its area of concern, the working group makes the following statements.

1. If there is an Institute, it should include CAI-related activities, but CAI is not sufficient reason alone for the Institute.

2. An Institute should not be established if it would significantly reduce the research funds available to universities or other research organizations.

3. Activities should be in support and development of prototypes and pilot operations, rather than central curriculum banks and networks.

4. In order for an exploratory development activity to be able to develop new pedagogical techniques at a cost efficient rate, with materials embodying it and to evaluate effectiveness requires (1) at least $1,000,000 per year and (2) students taking courses at an educational institution willing to innovate and cooperate with such experimentation.

5. If there is an Institute, the following CAI-related activities would be appropriate within its role as entrepreneur and promoter and exploratory developer:

   a. distribution of skills-acquisition courses (e.g., language learning) (probably at least five years away for complete economically feasible system);

   b. construction of environments in several disciplines (such as lens design, automated laboratories, gaming);

   c. systems analysis of higher education and its organization, of how CAI could be introduced, used, produced, rewarded;

   d. promotion of information gathering and refinement, need specification (e.g., needs in operating systems, terminals, standard program modules);

   e. promotion of education of instructors and administrators in the use of computers.

6. If there is an Institute, the following CAI-related activities would be appropriate within its role of supporting and sustaining important research (which role is considered essential to maintaining a viable Institute):

   a. natural language processing;

   b. man-machine interface research;

   c. studying the nature of problem solving.

INFORMATION SYSTEMS
IN EDUCATION
PROJECT ISE

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Neil Churchill, Associate Dean, The Business School
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Addendum to Part 1

SUMMARY:

A PROPOSAL FOR THE ESTABLISHMENT

OF AN

INSTITUTE FOR INFORMATION SYSTEMS IN HIGHER EDUCATION

15 April 1969

It is proposed that an Institute for Information Systems in Higher Education be established as soon as possible with operations to commence not later than 1 April 1970.

Purpose

The Institute will organize and carry out programs to extend the use and to enable more effective application of information systems in institutions of higher education. To assure that developments are realistic and widely used, the Institute will be closely tied to the higher education community through management and structure and will undertake much of its work with cooperating colleges and universities. The initial programs will focus on developing and installing administrative information systems and on the large-scale sharing of information system resources.

Size and Scope

The Institute will assemble, to serve in its initial programs, a staff of about 160 people by the fifth year. It will be concerned with problems of long-range significance to many educational institutions as well as those too difficult or costly to be attacked by a single college or university, or group of such institutions. To encourage use of techniques developed and increase competence in information systems at the campus level, the Institute will involve active participation by large numbers of visitors from the academic community as well as operate a substantial program of work in the field.

Activities

Initial activities of the Institute will be undertaken in the two program areas which follow:

Addendum to Part 1
Summary: A Proposal...

An Administrative Systems Program concerned with analysis and modeling of the administrative process and development, implementation and field testing of specific components of operational information systems.

A Resource Sharing Program concerned with development of methods and techniques for the sharing of computer based system resources among large numbers of institutions. An initial task will be establishing a prototype resource sharing system involving approximately 200 institutions in a geographical region.

Schedule

It is proposed that the Institute start operations during the period 1 January 1970 to 1 April 1970. However, organization of a Governing Board consisting of outstanding members of the higher education community and application for charter as a non-profit corporation should commence shortly.

Funding Requirements

It is projected that operating costs in the first year will be approximately $900,000, rising to about $5 million in the fifth year. Under the plan proposed, essentially no capital funds are needed. To attract the leadership required for a successful operation, the full operating fund requirements for the initial five year period, an estimated $15 million, must be committed in advance.

Chapter IV

ADMINISTRATIVE INFORMATION SYSTEMS IN COLLEGES AND UNIVERSITIES

Introduction

An institution of higher education is a complicated system, constantly changing as the fields of knowledge grow, as understanding of the process of learning grows, and as society itself changes. Each institution has limited resources of manpower, facilities and funds, which can and must be used effectively in a wide variety of ways. Each institution should be in a position to make decisions at all levels and in all areas which will result in its resources being used to provide the best possible education at minimum cost to each of its students.

Thus, in its broadest context, an administrative information system is needed by the faculty to provide each teacher with current information on students to help realize a better learning situation for each student. The information system must also enable each faculty member to reduce to a minimum the time he spends on paper work. It must provide current information in an easily usable form to those faculty members charged with administering departments, schools and research projects in order to free them of routine and provide more time for the educational development aspects of their work. It must provide the president and his staff access to a wide variety of factual data regarding people, the physical plant, equipment, courses, research projects and proposed undertakings in order to develop strong planning efforts and sound information as to alternative courses of action on which to make important educational and management decisions.

Almost all information relating to each aspect of an institution's operation is interrelated. Student operations, with data on admissions, student records, etc., are clearly linked to:

1. Faculty and staff requirements and assignments;
2. Fiscal operations such as payroll, general budgetary accounting, billing, etc.;
3. Use of physical space and equipment;
4. Class scheduling and assignment;
5. Support of teaching.

All data are involved in planning and development with the focus on modeling of the institution, conduct of institutional research and projection of future needs. Obviously a university information system which would dynamically unify these many campus operations would be an extremely complicated system -- one which would differ in certain characteristics between institutions, but which, if it existed, would be of enormous value to all elements of an institution of higher education. While a basic or core system of data gathering, storage and retrieval is possible and might well be used by significant numbers of institutions, provision must be made for the satisfaction of particular or idiosyncratic needs of the individual institution.

An Integrated University Administrative Information System

A Definition...An integrated administrative information system for institutions of higher learning is defined as a system capable of providing accurate and timely information for decision making at all administrative levels. Such a system for university and college administration must support operations which for convenience are divided into three areas:

A. Student Operations
B. Personnel and Fiscal Operations
C. Planning and Development

Some of the activities in each of these areas are listed below:

A. Student Operations

1. Student records
2. Admissions
3. Registration
4. Scheduling and sectioning
5. Testing and other support of teaching activities
6. Counseling
7. Grade reporting
8. Alumni records
9. Financial aid
10. Health services

B. Personnel and Fiscal Operations

1. Personnel
2. Student accounting
3. Payroll
4. Purchasing and material management
5. Plan and equipment management
6. Income accounting
7. Investment management
8. General and budgetary accounting
9. Management of auxiliary enterprises such as residence halls, book store, etc.

C. Planning and Development

1. Modeling the institution
2. Institutional research
3. Consideration of alternative use of resources
4. Projection of future needs
5. Planning the development program to ensure the funding for future operations

Advantages...The advantages of a widely used integrated administrative information system for higher education include:

1. Providing more and better information;
2. Providing information rapidly -- in time to be useful in current decision making;
3. Lowering cost per unit of information handled;
4. Reducing the amount of file duplication;
5. Reducing the number of errors;
6. Freeing faculty and administration time for more important purposes and thus enhancing the better utilization of scarce resources;
7. Helping an institution discover where it is, where it is headed, and where it should be going;
8. Permitting a university to think about itself as a system rather than as a collection of essentially arbitrarily related units;
9. Making possible the consideration of alternative uses of resources and providing means for monitoring progress made toward the goals decided upon;
10. Providing a means for comparing one institution's output with others.

Difficulties...There are major difficulties in the installation of an integrated university administrative information system:

1. The university is a complicated organization and hence difficult to understand and represent in formal machine manageable language;
2. The design and installation cost for a single institution operating by itself is very high;
3. An apprehension exists among some students, faculty, and administrative personnel that the use of the computer will:

    a. tend to dehumanize the campus environment;
    b. tend to develop strong central administrative control;
    c. tend to decrease freedom of action at local level;
    d. tend to erode the privacy of certain information.

As to point three, however, many of the apprehensions may prove to be groundless. For example, several points have been made against the "dehumanization" argument. By freeing much of an administrator's and faculty member's time from clerical work, more attention can be paid to the individual student. In addition, an automated system would make it easier to bring "exceptional cases" to the attention of faculty or counselor.

As to centralization, the availability of good information does not in itself alter the nature of administrative control. Indeed, a university with strong local unit responsibilities can improve the functioning of the local units by providing important information in time to be used to the best advantage.

Machine files can be made as secure as conventional files now in wide use on campuses. Thus, safeguards in the system would limit file access to those who need various categories of information.

Though some of the difficulties are real, the need to overcome them is urgent. The proliferation of limited information systems in individual institutions reflects current interest in and concern with this problem.

The Fiscal Stake

What are the stakes involved now and in the future which make a better use of resources by all of our institutions of higher education so important?

From latest available figures published by the U.S. Department of Health, Education and Welfare for the year 1963-64,[1/] we note the following:

A.	Total operating expenses	$ 9,300,000,000
B.	Total endowment	7,000,000,000
C.	Total value of physical plant	23,000,000,000
D.	Percentage of -A- used for administrative expenses	10.5%

While it is difficult to make a reliable estimate of similar figures for the year 1979-80, it is likely that annual operating expenses will triple to approximately $30 billion in that year (see Figure 1, Enrollment Growth). Thus, a 10% reduction in those expenses due to better planned utilization of resources by a large percentage of all institutions of higher learning would mean a national savings of $3 billion in annual operating funds.

Similarly, it is likely that plant value in that period would also triple to a total plant investment of approximately $70 billion in 1979-80. Assuming an increase in that one year of between $6-8 billion in plant investment, a 10% reduction would result in a national savings of approximately $700,000,000.

The College or University System -- A Way of Viewing the Administrative Problem

A block diagram of an educational institution is shown in Figure 2. The major outputs of the institutions are educated men and women, contributions to knowledge, services to community, state, nation, etc. Some of these outputs are difficult to measure. Certainly the number of degree recipients and their fields of concentration can be readily determined. The increase in understanding and in the ability to use knowledge wisely due to the students'

1/ K.A. Simon and W.V. Grant, *Digest of Educational Statistics*, 1968 Edition. U.S. Dept. of H.E.W. Government Printing Office, OE-10024-68, Washington, D.C. 1968.

Figure 1

The Growth of Enrollment
in U.S. Colleges & Universities

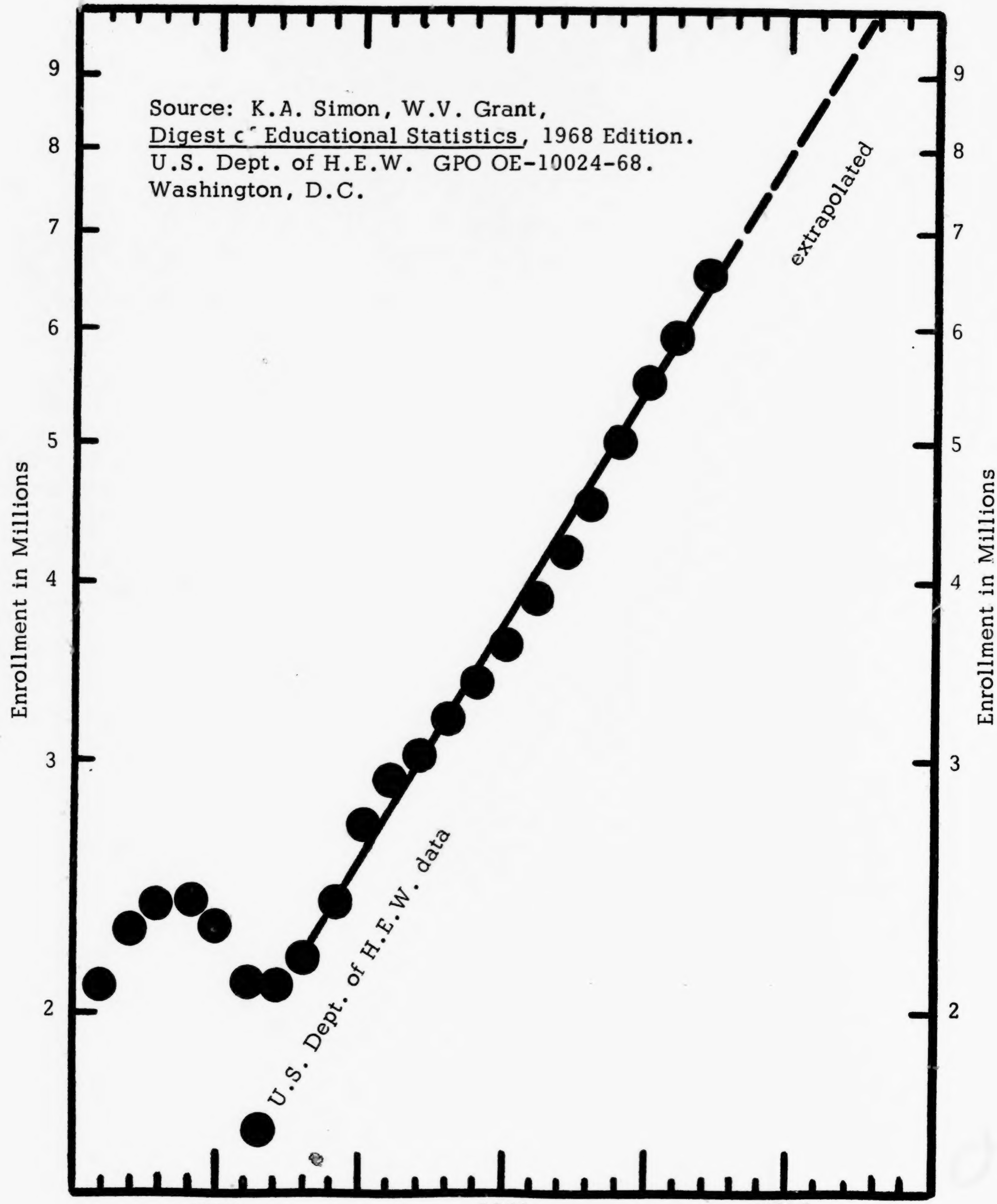
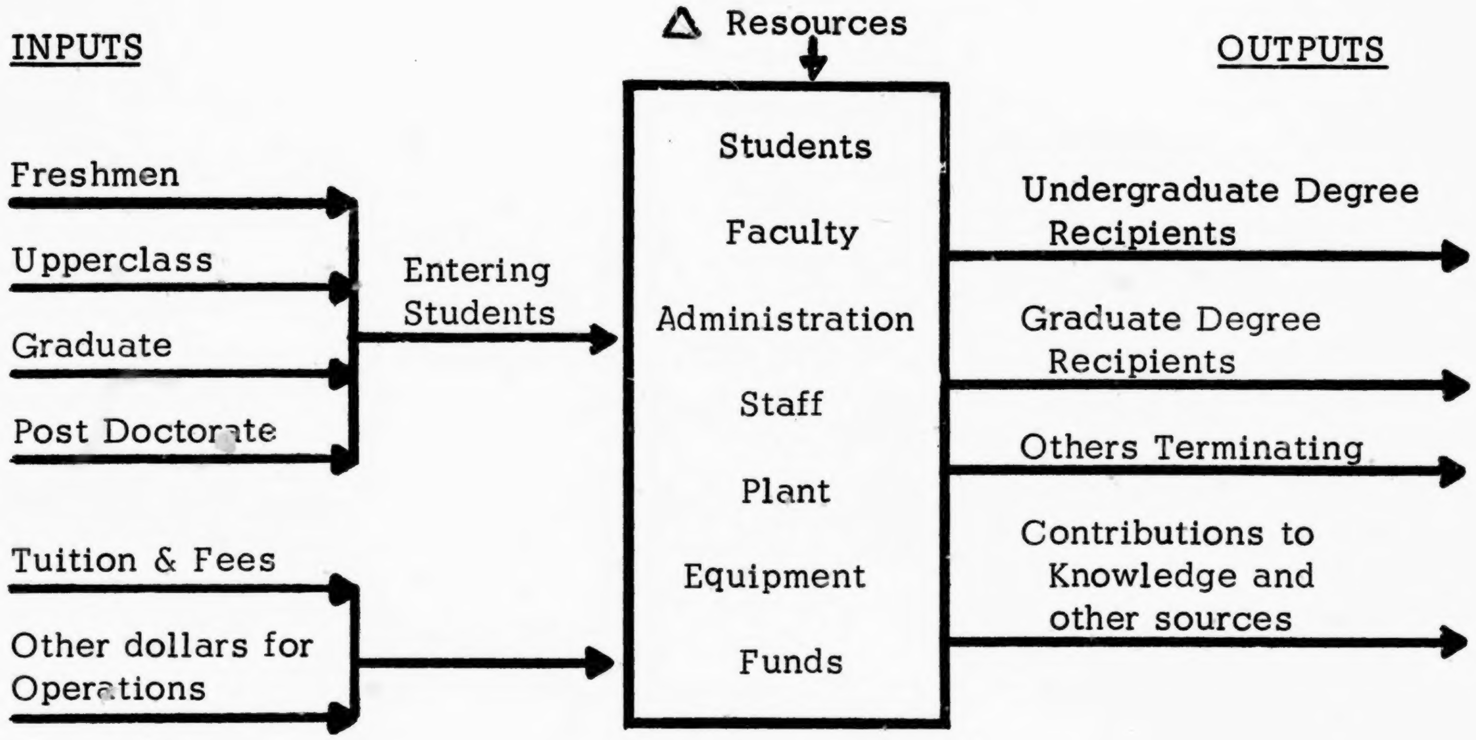


Figure 2

Coarse Grain Block Diagram
of an
Educational Institution


INPUTS
Δ Resources
OUTPUTS
Freshmen
Upperclass
Graduate
Post Doctorate
Entering Students
Tuition & Fees
Other dollars for Operations
Students
Faculty
Administration
Staff
Plant
Equipment
Funds
Undergraduate Degree Recipients
Graduate Degree Recipients
Others Terminating
Contributions to Knowledge and other sources

residence in a specific college or university is extremely difficult to measure. Similarly, the value of research results and service rendered cannot be as sharply stated as the net dollar profit output of an industrial company. Nevertheless, carefully conceived objectives related to the mix and relative importance of desired outputs of an educational institution are the prerequisites for decision making at all levels.

Objectives in terms of numbers of degree recipients (bachelor, master, doctor) can be set. Size and character of fields of study can be targeted. Size and to some extent nature of research activities can be projected. While it is true that actual outputs often vary from desired objectives, a strong continuing focus on institutional objectives gives direction to the shaping of the long time nature of the school and makes possible the careful consideration of the most effective use of resources in attempting to realize objectives.

Relatively simple analyses based on the coarse grain block diagram of Figure 2 can yield important information. Thus student attrition studies, cost per degree recipient, physical space to be provided per student (classroom, laboratory, dormitory, administrative and faculty offices, etc.) can be determined for various fields of concentration and compared to similar data at other institutions. Times in residence to complete MA, MS and PhD programs with attendant costs can be studied. Actions to make desirable changes can be planned. The influence upon costs of varying faculty-student ratio can be learned. Various distributions of class size can be considered with projections of the companion changes in required physical plant and other resources.

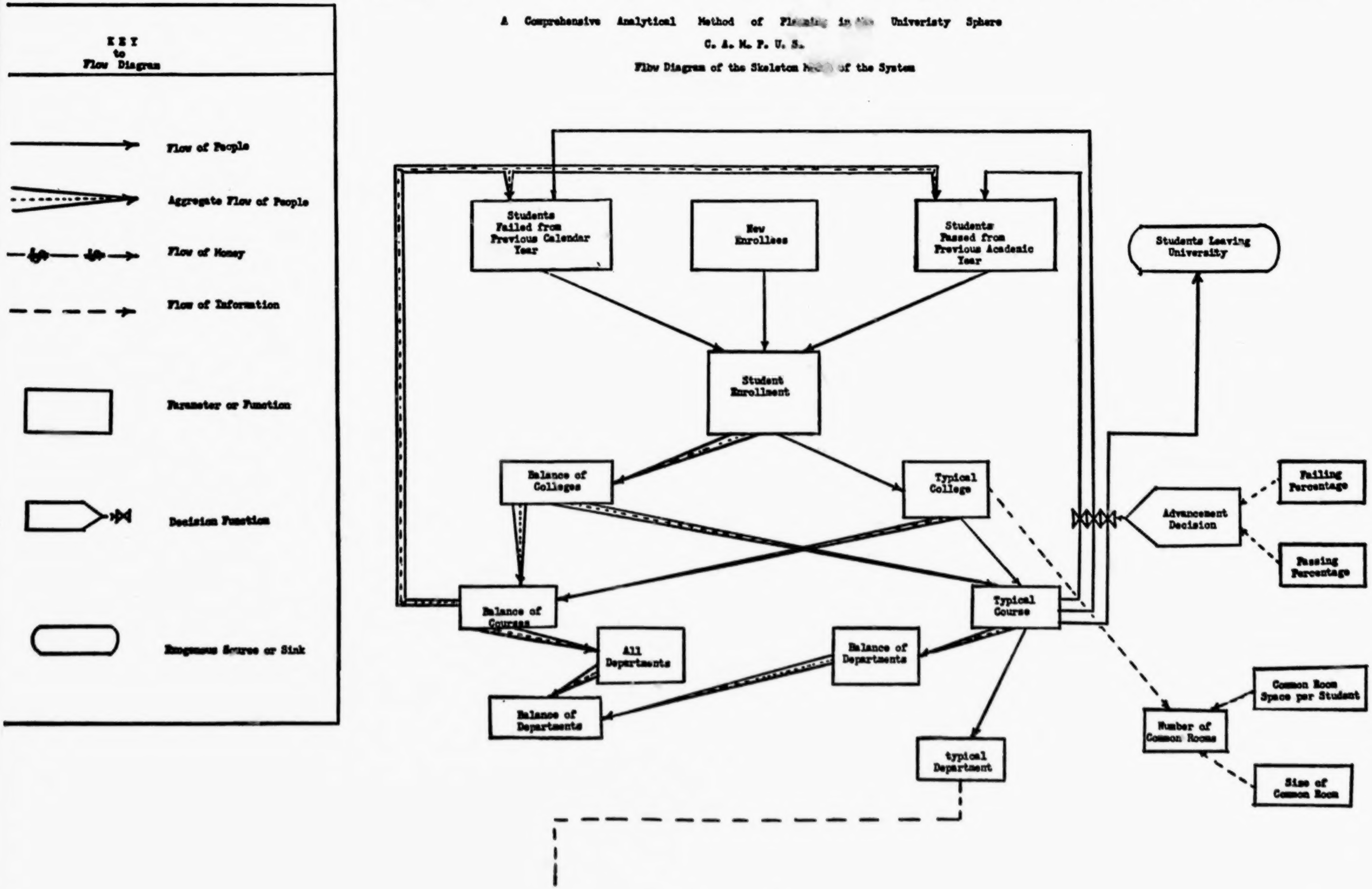
A thorough study at this level of decision making would define the kinds, detail, and frequency of data needed and by whom. In such an undertaking, care must be exercised to insure that what results ultimately is useful to many institutions.

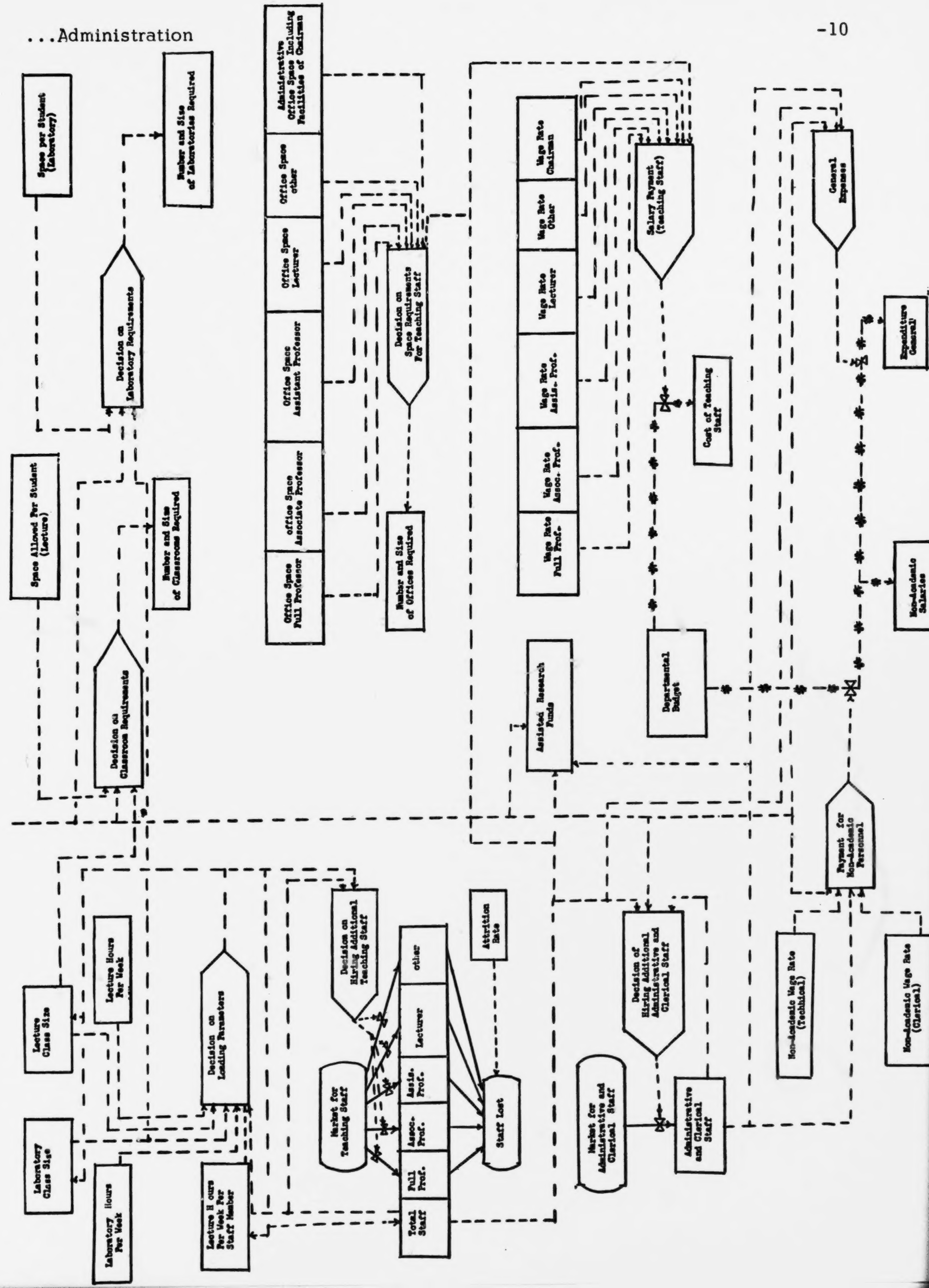
A considerably finer grain diagram of a model of a university appears in a report by Richard W. Judy and Jack B. Levine, both at the University of Toronto.[2/] It is reproduced as Figure 3. Clearly, progressively finer grain skeleton models are required to provide an appropriate framework for operational and planning decisions at all levels. Important to the support of such a system is a well designed information system.

2/ R.W. Judy and J.B. Levine, A New Tool For Educational Administrators, a report to the Commission on the Financing of Higher Education. Published for the Association of Universities and Colleges of Canada by University of Toronto Press. 1965.

Figure 3 2/

A Comprehensive Analytical Method of Planning in the University Sphere. Flow diagram of the skeleton model of the System (CAMPUS).


A Comprehensive Analytical Method of Planning in the Univeristy Sphere
C. A. M. P. U. S.
Flow Diagram of the Skeleton Model of the System
KEY to Flow Diagram
Flow of People
Aggregate Flow of People
Flow of Money
Flow of Information
Parameter or Function
Decision Function
Exogenous Source or Sink
Students Failed from Previous Calendar Year
New Enrollees
Students Passed from Previous Academic Year
Students Leaving University
Student Enrollment
Balance of Colleges
Typical College
Advancement Decision
Failing Percentage
Passing Percentage
Balance of Courses
Typical Course
All Departments
Balance of Departments
Balance of Departments
typical Department
Number of Common Rooms
Common Room Space per Student
Size of Common Room


Space per Student (Laboratory)
Number and Size of Laboratories Required
Decision on Laboratory Requirements
Administrative Office Space Including Facilities of Chairman
Office Space other
Office Space Lecturer
Office Space Assistant Professor
office Space Associate Professor
Office Space Full Professor
Decision on Space Requirements For Teaching Staff
Number and Size of Offices Required
Space Allowed Per Student (Lecture)
Number and Size of Classrooms Required
Decision on Classroom Requirements
Wage Rate Chairman
Wage Rate Other
Wage Rate Lecturer
Wage Rate Assis. Prof.
Wage Rate Assoc. Prof.
Wage Rate Full Prof.
Salary Payment (Teaching Staff)
Cost of Teaching Staff
General Expenses
Expenditure General
Non-Academic Salaries
Departmental Budget
Assisted Research Funds
Payment for Non-Academic Personnel
Non-Academic Wage Rate (Technical)
Non-Academic Wage Rate (Clerical)
Decision of Hiring Additional Administrative and Clerical Staff
Market for Administrative and Clerical Staff
Administrative and Clerical Staff
Attrition Rate
Staff Lost
Decision on Hiring Additional Teaching Staff
other
Lecturer
Assis. Prof.
Assoc. Prof.
Full Prof.
Total Staff
Market for Teaching Staff
Decision on Loading Parameters
Lecture Class Size
Lecture Hours Per Week
Laboratory Class Size
Laboratory Hours Per Week
Lecture Hours Per Week Per Staff Member

It is important to point out that many models are required to represent how various institutions are organized -- the different activities engaged in -- and the varying objectives set. Indeed, it is important that individual institutions frequently consider the consequences of changing their structure and their use of resources. Inherently, institutions of higher learning in the United States have unusual opportunities to fulfill their missions in diverse ways. Yet the ability to seize such opportunities is seldom present.

Progress on Campuses

Many institutions have recognized the advantages of automating administrative procedures and have computers for such uses. But these computer applications rarely extend beyond the mechanization of tasks which were formerly handled manually in routine and general accounting. However, relatively little has been done to explore the extension of computer based information systems into new functional areas and to initiate the development of new procedures which would be important components in assembling operational full-scale information systems on many campuses.

Clearly, the design and successful introduction of full-scale administrative information systems on the nation's campuses will require a great deal in terms of manpower, time and money -- and more of these resources than all but a few institutions could individually provide. Some colleges and universities have recognized this problem and have begun to pool their resources in cooperative ventures to create and implement limited administrative information systems which can be shared by several campuses. The National Science Foundation furnished grants in early 1968 to Cornell University, Dartmouth College and Oregon State University for programs in which each of these institutions will serve as a regional computing center furnishing, among other things, administrative data processing services to a group of educational institutions. In a few instances an automated procedure developed on one campus has been used elsewhere. Thus, the admissions system designed by the University of Massachusetts has been adopted by the University of Rhode Island and in modified form by New York University and Harvard. The Purdue scheduling system has been used by the University of South Carolina, Seattle University and the University of Illinois. A number of state systems have undertaken important developments as well. Generally, however, computer application studies have been singular ventures, designed for implementation in just one institution.

In 1968 the Ford Foundation made a significant group of grants to four universities (University of California at Berkeley, Princeton University Stanford University, and the University of Toronto) to support the development and testing of new techniques in administration, principally through the use of computer based systems. It is interesting to note that the Foundation, in its announcement of this program, stressed that "When you see the mounting pressures on our colleges and universities, better management may be their only way to sustain their academic freedom. You don't take the vitality away from a dynamic institution merely because you know something about its component parts. You do not necessarily dehumanize a university when you try to take the measure of its problems."

A survey made by Rourke and Brooks for their book, The Managerial Revolution in Higher Education, found that 53% of the 134 state universities responding to the questionnaire use computers for administrative purposes. 3/ This figure jumped to 90% for such institutions with enrollments over 10,000. When the number of major private institutions is added to these figures, it becomes obvious that many different admission, registration, scheduling and other systems have been designed and that a considerable amount of expertise exists that is now scattered over a number of campuses.

Despite this demonstrated deep interest of higher education institutions in administrative information systems, it is known that shortages in skilled manpower and financial constraints are severely limiting progress. In the Pierce Report 4/ the estimate was made that computer costs were rising by as much as 45% per year in many institutions. The report estimated that the total cost of providing educational computing, excluding administrative activities, averages about $60 per student per year, and that to meet this goal by 1972 the cost for all colleges would rise from $100 million per year in 1968-69 to $414 million per year in 1971-72. In several of the leading institutions which now represent the most advanced examples of use of computer based systems, the total cost per student already has reached as much as $600-$800 per year. At present the largest portion of that amount is devoted to research activities.

3/ Francis E. Rourke and Glenn E. Brooks, The Managerial Revolution in Higher Education. The Johns Hopkins Press, Baltimore. 1966.

4/ John R. Pierce, et al. Computers in Higher Education. Washington, D.C. The White House. February 1967.

A Growing Need for Further Action

While the development of regional resource sharing and the expected reduction in the cost of computing equipment will help make the cost of computing on campuses manageable -- and much research, development and experimentation in this area are needed -- it does not follow that progress towards administrative information systems in most higher education institutions will accelerate. Some of the formidable obstacles which exist are discussed below.

Existing administrative information systems in many an institution of higher learning have been carried over from the early beginning of the school with relatively minor changes introduced as forced by circumstances. Such systems, often using computers, have evolved to handle current operations with little attention given to the need for future planning. The systems which exist often are operated with a minimum size staff. Creative work in the design and implementation of an effective administrative information system is neither encouraged nor rewarded in the same manner as similar work in industry is or as achievements in academic activities in colleges and universities are. The result is that many of the nation's institutions of higher learning have heavily overworked staffs constantly facing peak work load crises in registration, in class assignment, in preparation and distribution of grades, in attempting to furnish status reports on various accounts which are current enough to be useful in budget control, in attempting to get data to respond to the increasing demands for information from various governmental organizations. While many devoted, able people carry on under these circumstances, a substantial number of talented, urgently needed people move to higher paid and often more interesting jobs in industry.

In spite of such difficult conditions, many institutions have and are trying to install improved information systems. Such efforts are too often characterized by insufficient funding, limited goals, and inadequate manpower to maintain the current operating system -- design a better one -- and live through the transition period required for the installation and debugging of an improved system. Usually the resulting system is applicable only to the given institution and only partially meets original objectives. Such efforts and results are duplicated on a number of campuses.

The need for more effective use of available resources -- the need for acquisition of additional resources -- the need to think of better ways to organize the human resources of higher education -- the need to evaluate existing operations -- the need to be able to understand how learning takes place -- the need to be able to make reasonable predictions as to the probable results of alternative ways of carrying on college and university business -- are becoming increasingly urgent.

Recognition of such needs is growing and is reflected by the build-up of planning activities in a few institutions and by the increased volume of publications concerned with the institution of higher learning as a system.

Thus, the internal forces for improvement in information systems are rapidly increasing. But so are certain external forces. Potential students desire a better picture of the institutions they are considering as do secondary school principals and guidance officers.. Many alumni wish to understand as fully as possible the changing nature of their alma mater. Foundations are seeking far better information concerning operations and planning from applicants for grants. State and federal governmental agencies responsible for appropriations to educational institutions are requesting better supporting material. Researchers in higher education find it extremely difficult to get comparable data from different institutions. These external forces of pressure for more and better information also often need that same information in similar format from many institutions of higher learning. Such forces, though growing rapidly in magnitude, are not new. Yet they have not as yet produced the effective continuing responses needed from the universities to fulfill these pressing needs.

What Needs to be Done

While urgent requests for help in improving administrative information systems are coming from many colleges and universities, most clearly revealed by the rapidly growing volume of proposals to governmental organizations and private foundations, there are differing viewpoints as to the relative urgency of the various actions required. Although such views are diverse, they divide into essentially two categories. The first category, which perhaps attracts the larger number of adherents, might appropriately be called "the put out the fire first" category. Thus, registrars, business office managers, vice presidents, faculty members in charge of research projects, and even presidents -- under conditions of increased enrollment, growing research activities, growing community and governmental relationships -- often say, "Just help us get out the information we need today to limp along, and sometime in the future we may have the time and resources to reshape our entire information system." In fact, it may well be that no useful "information system" even exists in such instances.

Another and perhaps smaller group of people holds the position that, while certain things can be done to respond to such pressing needs, the avoidance of continually recurring crises and the imaginative use of its resources by an institution of higher learning require a longer range, more comprehensively developed framework for thinking about the college or university with the full use of modern system analysis and synthesis techniques. A comprehensive computer based information system, to support decision making at all levels and the implementation of such decisions, could then be designed. While action in accordance with one of these viewpoints does not exclude action in accordance with the other, there are strong reasons for believing that a relatively large-scale, long-range program shaped according to the second viewpoint will have the greatest payoff for the largest number of institutions.

Need for a Long-Range National Effort in Administrative Information Systems in Higher Education

Few institutions would take the position that they could not improve their use of resources or current operations if they had access to the continuing effort in planning which is required. While one might be reluctant to estimate the possible national savings at 5%, 10% or 20% and one might argue for some trade off between increased quality and dollar savings, there exist strong viewpoints that substantial national institutional gains are possible. For the nation to realize its potential gains, a substantial number of the institutions of higher learning in the country must participate. How can this be done? To respond, some statistics showing certain characteristics of the nation's colleges and universities are summarized below.

Approximately 1,600 educational institutions with 3,000 or less students each enroll one-third of the students of higher education in the United States (see Figure 4). About 170 institutions with 10,000 or more students each enroll about one-half of all U.S. students in higher education.1/

Not only are there tremendous differences in size but there are other important distinctions. Some are four year undergraduate colleges. Others are universities with large undergraduate and graduate student bodies --

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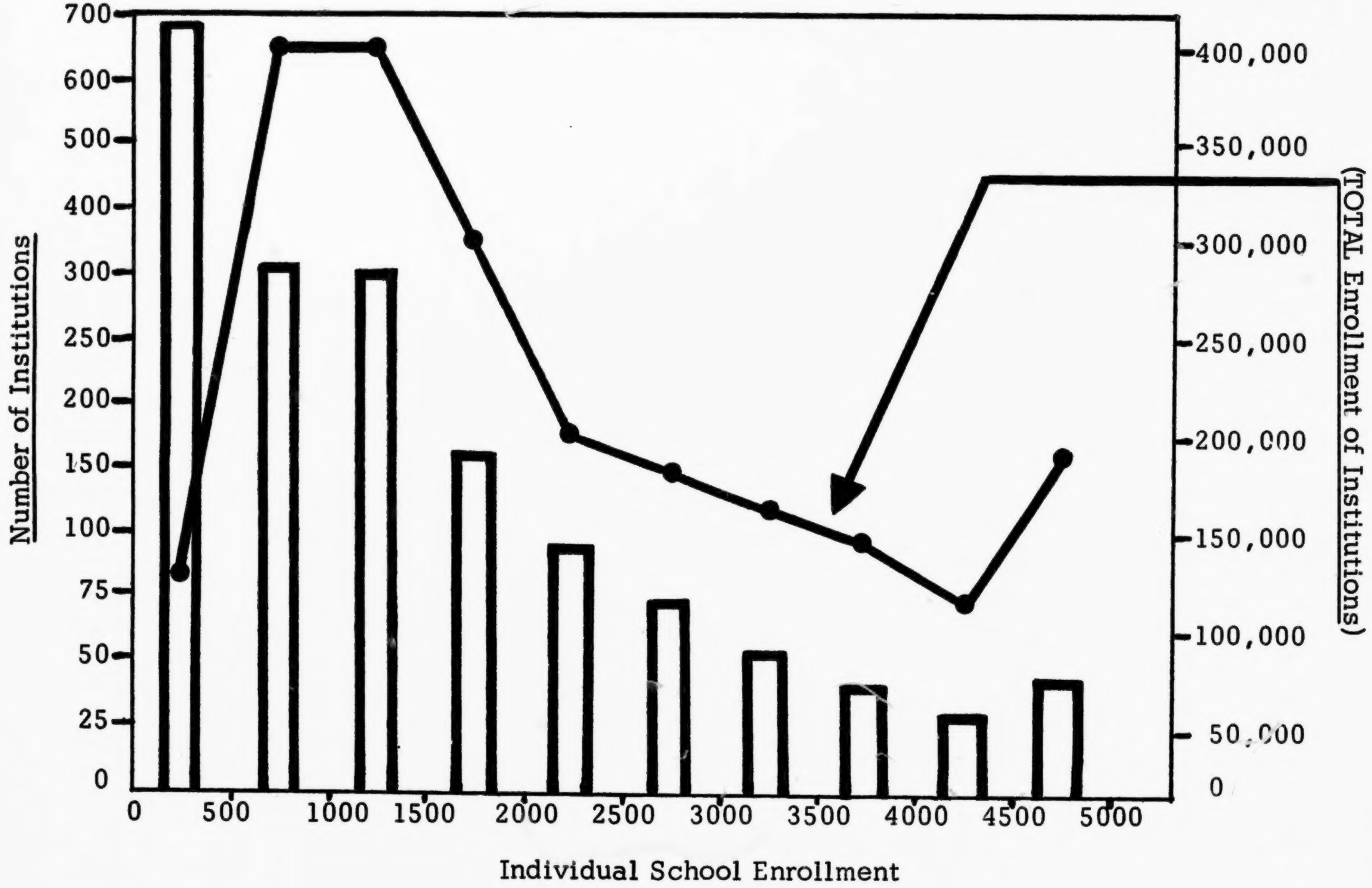
1/ See footnote, page 5.

Figure 4

Distribution of Students in Institutions of Higher Education Arranged According to Enrollment of Institution



professional schools -- some have strong hospital affiliations. Some have large research programs. A few manage large, governmentally owned laboratories. Some have extensive overseas programs. Some are private institutions. Others are operated as state or municipal institutions. A growing number have substantial fiscal support from both private and public sources. The fastest growing category, both in number and enrollment, is the two year junior college.

While the great diversity of character of the U.S. educational institutions of higher learning poses a serious challenge to a national effort to assist in the installation of greatly improved administrative information systems, nearly all of those institutions have similar tasks which such a system would support.

Applicability of Results

Considerable thought and planning must be given to the extensibility of information systems for use in a wide variety of colleges and universities having diverse needs and hardware. Unique facilities for each of the 2,300 institutions of higher education are clearly both uneconomic and undesirable. Maximum practicable commonality of information systems can permit shared development at lower cost per user and can aid desirable inter-institution cooperation. It is, however, simplistic to suggest that a single system can fill every need. A reasonable balance should be sought.

Grouping institutions which have substantial similarities in background, outlook, resources and facilities can provide opportunities for standard packages. Whenever feasible, such standardization should be encouraged and exploited. New junior colleges, for example, are expected to be a fruitful field for such cooperative developments. Designs should utilize the maximum practicable parameterization to extend applicability by leaving most options under the individual institution's control.

Many colleges and universities, however, have unique requirements which will not be satisfied by standard options. Their needs can be met best through assemblage of modular components. A school that would not adopt a complete student record system, for example, may find it highly desirable to use a proven prediction of yield analysis from an admissions subsystem. With care in design, such use of modules can be greatly facilitated. Substantial savings and highly desirable commonality could result. In time, as the number and diversity of modules increase, a large fraction of national needs probably could be met through linkages of available components.

Beginning information system implementation with the smaller and less complex colleges has the substantial advantage of encouraging modularity. The large number and varied types of colleges will insure that maximum attention is paid to full parameterization and module segmentation. Lessened complexity will promote quicker testing of ideas in actual operating environments to promote greater realism. And, since even the largest universities incorporate many of the functions of colleges, components developed for the small should be applicable to the large. Foresight and careful modular design will be needed to help maximize the exploitable commonality.

The wide variety of hardware available on the nation's campuses makes "machine independent" implementation techniques essential. To be sure, it is still not practicable to make one program run without change on many disparate computers. The proper choice of languages and design principles, however, can make a substantial difference in the cost of moving from one machine to another. Implementation should take full advantage of every available means of minimizing transitions.

Full use of the "machine independence" of widely available, higher level languages (such as Cobol) can contribute significantly to easing movement. Implementors should be kept aware of the often subtle differences between available translators by being required to debug their programs on several disparate machines. This salutary experience has proven to be most useful at other installations in minimizing the introduction of machine dependent features.

Even with the best skills and finest intentions, execution speed or storage utilization problems can force some departures from higher level languages. When this happens, assembly language programming can and should be done in a manner which minimizes transition problems. Any assembly language procedure can be implemented as a sequence of macro-instructions. Such macros, if carefully chosen, can be formulated independently of particular hardware. To use a procedure written in macros, the macros must first be defined in terms of the specific computer's instructions; a macro-assembler can then convert the procedure into machine language.

Although the use of macros requires highly skilled programmers, who are in exceedingly short supply, the cost of preparing an assembly language level program through "machine independent" macros can be much less expensive than tailor-made programs for each of a large number of computers. The macro approach, in turn, is more expensive than use of higher level languages -- when they are applicable. Each technique, therefore, has its merits in realizing the maximum practicable degree of "machine independence". Used together, they can substantially ease the cost of moving software from one machine to another.

A few institutions will undoubtedly want to continue development de novo. Such activity can be justified, particularly to meet unique circumstances. These institutions and a central system, however, will have a mutual interest in maintaining close contact to insure full use by both of the ideas developed by either.

The National Science Foundation, in cooperation with the U.S. Office of Education, in funding the AUI-ISE project, has evidenced its deep concern with this complex national problem.

Work to date by Project ISE concerning university administrative information systems indicates that the implementation of such systems in a great many colleges and universities of the country is an important objective. Secondly, such systems can be designed which would be sufficiently flexible to be used by hundreds of institutions in this country. Finally, the achievement of the task is one of the services an inter-institutional laboratory for information systems could perform. A proposal for the creation of an Institute for Information Systems in Higher Education, with initial emphasis on administrative systems, has been drafted.

Research Activities

An important role of such an Institute is to provide new understanding that will lead to more effective use of resources. The modeling of institutions of higher education, the simulation of a variety of courses of action, and the implementation of working information systems in many colleges and universities are important and long-range undertakings. Much can be done using existing knowledge and techniques. In addition, the need for further thought and analysis on many important problems will become even more apparent. Thus, an important activity is continuing research on broad based problems of interest to many institutions. A list of such problems might include:

1. Long-range projections of capital and operating costs of new activities with due attention to such things as:

    a. nature of activity -- in science, in engineering, in social sciences, in humanities and arts, in the professional school, etc.;
    b. various levels of undergraduate, graduate, post doctoral, and research activities;
    c. alternative uses of human and physical resources;

2. Continuing studies of alternative ways of supplying various levels of computer usage for instruction, administration, research, the library;

3. Studies of investment and fund utilization strategies under differing institutional conditions and time variant factors in the economy;

4. Development of guides for library planning for:

    a. new institutions;
    b. established institutions of varying sizes, objectives, and current library operations, with due consideration to

        existing information systems technology and projected developments in existing information systems technology;

5. Studies of various class size distribution versus cost and learning effectiveness for various models of using human and physical resources including all desirable technology.

Another series of problems of major concern lies in the field of information and computer science and technology and includes:

1. Transferability of working computer programs among many computer installations;

2. File protection;

3. Solution of man-machine language problems for many users.

Implementation of Effective Administrative Systems in Many Institutions

The effective use by many institutions of higher learning of administrative information systems of similar design would result in major savings for individual institutions and for the country at large, as previously pointed out. Such an achievement requires a major continuing effort and involves:

1. The initial design, testing, debugging, and continual updating of a desirable system;
2. The development of a nationwide educational program for administrative personnel at all levels of decision making;
3. The development of effective means for meeting the various human and organizational problems which so often cause great difficulty in making any changes to existing systems;
4. The development of realistic resources needed during a transition period from an existing system to a new, fully operating system;
5. The conduct of long-range R&D of importance to more effective use of resources.

To know first hand the nature of these problems and to solve them successfully requires an effective working relationship with a relatively large number of colleges and universities of diverse character. This is an important reason for establishing the major resource sharing activity involving some 200 institutions which is discussed in Chapters III and V.

The task is a large and continuing one which will involve the productive efforts of many institutions and of important segments of private business (management consulting firms, computer manufacturers, computer software and service companies, and others). However, present individual and small group undertakings involve much duplication of effort and limited scope activities, with little chance of implementation on a large, national scale. One of the strong recommendations of this report (Chapter III, Part 1) is the establishment of a national center which, it is believed, will make the efforts of all much more useful.

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Chapter V

INFORMATION SYSTEM RESOURCE SHARING IN HIGHER EDUCATION

Introduction

An important factor in achieving the goal of bringing the use of computer based information systems to a substantial majority of the 2,300 institutions of higher education is effective use of existing and potentially available resources -- equipment, manpower, software, educational programs. In most instances, such effective use of resources will depend upon a large-scale, cooperative research, development and evaluation effort in such areas as administrative systems, instruction, research, the library, etc.

Such cooperative efforts, herein referred to as resource sharing, can take a number of forms. For example:

1. Computing equipment located throughout an area can be shared by a number of institutions;
2. Several institutions can cooperate in the development and/or use of software packages in administration, instruction and research;
3. Competent people can participate in the development of a program of educational activities in information sciences which could serve many institutions and students.

If a significant number of the some ten million students who will be in institutions of higher education by 1980 are to benefit from the use of computer based systems in education, resource sharing on a national scale must play an important role. The discussion which follows offers some observations on resource sharing as it exists today and some of the actions which seem necessary to extend the principle in a major way throughout American higher education.

Resource Sharing Today

Information system resource sharing has become widely recognized for its potential contribution, and a number of interesting and useful projects are underway (see Appendix 1). Some of these efforts have made substantial progress; others have high aspirations. Is the problem, therefore, being solved? A brief review of two representative resource sharing projects will help answer this question.

> TUCC-The Triangle Universities Computation Center is a non-profit corporation, wholly owned by the University of North Carolina, North Carolina State and Duke University, and dedicated to supplying their people with computing service. TUCC is considered by most an unqualified success. It is evident that this resource sharing effort is realizing substantially more power per dollar than three separate systems. The thruput of its central computer is reported to be six times that of a machine of one-third its cost; that is, cost for equal service is cut in half. Furthermore, TUCC is offering substantial fringe benefits (such as stimulating joint endeavors and permitting massive calculations) that would be difficult or impossible to obtain if the universities had gone their separate ways.
>
> The Center's success rests on substantial initial advantages. Foremost is the fact that each participating institution was already deeply involved in computing under the direction and with the participation of extremely well qualified people. Each clearly understood its needs and jointly they had formulated an excellent plan for filling them cooperatively. The campuses involved are all within thirty miles of each other. TUCC began with all new equipment designed by a single manufacturer to work together. The program received substantial financial support.
>
> Anyone interested in resource sharing can gain much by studying Triangle Center's outstanding accomplishment. It is clearly an example of what is possible in today's state-of-the-art. But has it solved the national problem? The people at TUCC would probably be first to insist that it hasn't.

The President's Science Advisory Committee, in its report Computers in Higher Education,[1/] recommends the extension of computing to all students of the nation with "service at least comparable in quality to that now available at the more pioneering schools." Triangle Center stresses and succeeds in serving three institutions at this level and is providing modest services to 41 smaller institutions. To do the same job for all of the nation's 2,300 colleges and universities would require hundreds of such centers! This certainly won't happen.

TUCC was able to utilize all new and compatible hardware from the same manufacturer. Even assuming that the educational community's tremendous present investment in computers could be thrown away and all equipment needs fulfilled by a single manufacturer, the problem of connecting hardware from several suppliers must still be solved. A national computer based information system will represent such a huge investment that it must survive and prosper while absorbing changes and improvements, just as the great national electrical and telephone systems persist and operate well, despite the installation, over a period of time, of new and radically improved facilities. The ratio between costs and benefits in computer based systems is expected to improve even faster in the next few years than it has in the past. Any system that demands identical equipment for continuing expansion will quickly become obsolete.

> ARPA-The Advanced Research Projects Agency is currently sponsoring an effort to link computers of different manufacturers. In the initial configuration, geographically widely separated Univac 1108, IBM 360/67, SDS sigma 7 and SDS 940 units will be connected to each other over leased, high-speed, communications lines. An additional, small computer at each node will serve as the communications controller and provide the standard interface. When completed. the system will permit a user at any of the four machines to call for the execution of a program at any other.
>
> Most present thought about resource sharing is aimed at distributing raw computer service. It is particularly interesting, therefore, that each node of the ARPA system is already adequately supplied with its own large and powerful machines. Its aim is quality and diversity of access, not quantity. All advanced users share the need for a wider variety of software resources; the ARPA experiment intends to show how these can be provided economically.

[1/] John R. Pierce, et al. Computers in Higher Education. Washington, D.C. The White House. February 1967.

> Although the ARPA system is still in the proposal stage,[2/] work will start soon. The system is well designed, amply financed, and its objectives will unquestionably be met. Therefore, it seems safe to assume that multi-manufacturer linkages will soon be "the state-of-the-art".

Ultimately, the ARPA system will connect twenty different installations throughout the country. In contrast, TUCC's primary service is to three campuses within thirty miles of one another. Yet, no unsolvable problems are anticipated in the nationwide extensions. Thus, ARPA's project will be a significant step toward eventual construction of what might be called a national "computing utility". But more than replication will be required to fill the educational needs. ARPA's proposal has made basic design improvements to gain a factor of ten over TUCC. Clearly, even more advances will be required to obtain the remaining factor of 100 which is necessary to serve all of the nation's colleges and universities.

Bridging the Gap

In developing a resource sharing center, the gap between serving twenty institutions and a total community of 2,000 is obviously too great to span in a single leap. An order of magnitude increase from 20 to 200, however, would seem to be practicable. Furthermore, about ten centers of this size could fill most of the educational community's computer based information system requirements. Such an arrangement would appear to be logical, particularly since some decentralization would be desirable even if a single center were possible. A project, therefore, which proves the feasibility of serving about 10% of total needs would be an appropriate next step in information system resource sharing.

The realization of a computer based information system to serve 200 campuses, however, is an incredibly difficult task. It cannot be done quickly or cheaply. It must utilize the techniques and insight developed in the various smaller resource sharing projects. It must apply tools developed in related technology, such as the communications industry. It must be able to exploit existing hardware resources and advance with the availability of future hardware. Its developers must obtain the enthusiastic cooperation and assistance of numerous individuals and institutions. As

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2/ Defense Supply Service Request for Quotations DAHC 15 69 Z 0002, dated 1968 July 29.

a group, they must be well organized, carefully directed and amply funded. They will be faced continuously with the identifications of a wide spectrum of problems, both technical and managerial, and must find ways of moving effectively to useful solutions.

The key to success, in such a difficult and sizable undertaking, is to advance in a series of manageable steps offering significant and continuing incremental improvements toward a substantial but realistic goal. Development of the system, therefore, should occur in well defined phases.

In attacking a problem of the proposed magnitude, many complications will naturally occur and any that can be avoided must be. Aims must be kept reasonable. For example, an essential central feature or aim of the proposal is to provide users with a degree of "machine independence". Interpreted literally, this aim is meaningless. It is possible for any tyro to write programs for only one of a pair of machines which are identical except in some trivial detail, such as the number of tape drives. But, when reasonably interpreted, the concept of machine independence is extremely valuable. For, by careful system design, most users can and should be freed from concern with the details of particular hardware. A trivial plan will ignore such problems; an incompetent one will treat them cavalierly; a serious one will propose reasonable compromises.

The intent of a resource sharing program should be to fill the needs of the majority. The greatest benefits will be realized through serving most of the potential users. At the same time, the greatest problems will arise from trying to accommodate everyone in a single system. The optimum strategy is to expect that some requirements will continue to be met by dispersed, stand-alone machines. As time passes and technology progresses, the system can grow to fill these other needs. But it must not be prematurely stretched or it may break under the strain.

Finally, emphasis must be kept where it belongs -- on people. Hardware and software are essential components but they are only means to an end. The objective is to provide service to a multi-institutional community of users who have a common interest in computer based information systems. Service is more than simply computer time; it includes help in applying that time effectively in information systems related to campus problems and activities. A commitment to meet actual needs, maintained throughout the construction of the system, will keep the project responsive to the evolution of user understanding as well as to the potential of new developments. Both of these elements are essential to success.

Concept for a Regional System

Let us consider the Northeast region of the United States as a possible site for the proposed regional resource sharing system (described in Appendix 4 as North East Area Resource Sharing-NEARS). The object is to pool the existing computing and information system resources of the region to:

1. Bring effective computation services to approximately 200 institutions in the area;
2. Promote the fullest practicable use of existing equipment, particularly in on-campus information systems related to administration, instruction and research;
3. Make most effective cost/benefit decisions in adding computing equipment as increased demand develops;
4. Make a wider range of capability available to everyone; and
5. Design and prove the technology which can construct a national resource sharing system for higher education.

The development of this first resource sharing Center can benefit substantially from the Northeast's:

1. Large number of colleges and universities in a relatively small area;
2. Great diversity of kinds of institutions; and
3. Existing smaller and limited scale projects in resource sharing, such as the New England Regional Computing Program's (NERComP) experience with more than 60 campuses working together in computing.

In the proposed concept for a regional system, no provision is made for it to supply computer "power". In electrical parlance, the Center will be a "power grid"; it will "distribute" -- not "generate" -- computer "power". Its intent is to link the "sources" and "sinks" of the area for everyone's benefit. The Center would thus be independent of the ownership of those "sources". In the beginning, they will obviously be the available computers; ultimately, they will undoubtedly be the most efficient "generators". In any case, the "distribution" function of the Center will continue to be essential.

A fundamental aspect of this concept is the Center's contribution in research and development to the solution of the problems of large-scale resource sharing systems. It is not envisaged that the Center will become a computer "utility"; its purpose is to develop and prove an operational system. Service must be provided to do the job, but this function is expected to be transferred to a separate operating organization as rapidly as practicable.

Plan for Development

The plan suggested for the development of a regional resource sharing system involves the following rationale:

1. Enlisting the support and aid of colleges and universities;
2. Starting with clearly attainable objectives;
3. Using existing computer and information system resources;
4. Exploiting all available relevant techniques;
5. Building by surely achievable steps which provide increasing usefulness, thereby
6. Moving toward a substantial goal, while
7. Placing major emphasis on active use of the facility throughout its development.

Because of its objectives -- the attainment of ever more adequate capability to meet demands involving increasing degrees of complexity and the need for increased computing power -- development of the system will be undertaken in a series of phases, with completion of each phase producing an enhanced, self-contained system. Thus, each phase will offer a convenient check point on attainments, with the accompanying opportunity to adjust the program in accordance with changing requirements.

> Phase One: Initial effort will be devoted to establishing the basic service which will be the foundation of the Center and its system. An inventory will be made of the region's existing requirements and resources and training and consulting

services will be established to promote sharing of existing hardware and software to solve current problems. Transfer of information between users and computing installations will be by available transportation (mail, courier, etc.). At the end of this initial period, any institution in the region seeking assistance in implementing at least a minimal information system can have access to the people and machines that can provide it. Essentially, the remainder of the Center's development will be devoted to sustaining, extending and improving this basic service.

Phase Two: User performance is principally determined by turnaround time; information transfer by mail means that days can elapse between the submission and return of a run. Thus, the limiting component in the Phase One system is transportation delay. Phase Two will reduce the delay substantially by introducing electrical connection between users and machines. At the end of the second year, a suitably equipped user will be able to dial the Center on an incoming Wide Area Telephone Service (WATS) line and be connected (by a human operator) over an outgoing WATS line to the computer he requests. This shared use of WATS will reduce total communications costs considerably.

Phase Three: The next effort will be to remove the human operator. As an essential step toward building the system, switching will be done by a centralized, general purpose communications processor. Users will then be able to dial the desired computer through the Center and still benefit from the economy of shared WATS lines. The same processor will continue to be used for subsequent phases.

Phase Four: Until Phase Four, users, communications lines and computers must be available at the same time. Yet, the bulk of usable computing resources is usually available at hours which are inconvenient to users. The next step, therefore, will be to add a store and forward capability to the communications processor. When this phase is completed, users can call the Center and leave a job for subsequent execution. As WATS lines and the desired computer become available, the communications processor can forward the job, accept the results and return them to the originator.

At this point in the project, as a consequence of the experience gained, replication of the operation to bring the advantages developed by the Center to other regions of the country is possible and perhaps desirable. These new regional offshoots are visualized as being primarily independent service organizations which will exploit existing and future developments made at the Center. Appendix 2 shows a suggested ten-region division of the states; the actual regional set-up, of course, should be determined by the needs existing when the new regional systems are developed.

Phase Five: The next step will be to reprogram the communications processor to provide limited inter-system compatibility. When Phase Five is completed, users with remote terminals will be able to transfer information to any computer in the system, even those of a different manufacturer.

Phase Six: Effort will be made in this phase to introduce load sharing on a "let the buyer beware" basis. Users can ask for and get the cheapest (or quickest) compile and run of programs written in higher level languages. Responsibility for "machine independence" of that program, however, rests on the requester.

Phase Seven: Next, a standard programming language will be developed and compatible translators provided for all major machines in the system. Characteristics significant to the user will be definable by the user; undefined characteristics will be set to optimize the performance of the particular machine which will execute the program. Users of this language will be able to run their jobs on the most accessible computer with confidence in the results. Thus, load sharing will become practicable and each computer in the system can be more equally utilized.

Phase Eight: The goal of this phase will be production of a system standard, machine independent operating system. This development will permit effective inter-machine communication and use of shared storage.

Phase Nine: To reduce the cost of transmitting redundant information between users and computers, a central, shared storage facility will be added to the communications processor.

> Phase Ten: The tenth and final phase will decentralize the communications controller to make the system less dependent on the reliability of the Center's hardware. At this time it is likely that an orderly transfer of the regional network to a suitable operating organization will be carried out. The research and development Center initially responsible for developing the system, however, is expected to continue its fundamental work in improving resource sharing techniques and servicing the national requirements in this area.

The ten phases outlined above suggest a balanced development program and depend on using anticipated advances. Thus, a higher rate of expenditure in the program would not necessarily give a proportionate increase in progress.

Using the System

The "power" of the proposed regional resource sharing system is practically worthless until it is used. Yet, a majority of the over 200 campuses in the region have at present little or no capability in the use of computers. If the system is to fulfil its objectives, these prospective and presumably interested users must learn to apply its "power" to the solution of their problems.

Developing the capability on the part of the less experienced institutions to use the system will place a heavy responsibility on the Center. The Center must create and support a staff to help provide the needed instruction to the large numbers of people expected to be involved in the program. But this is only a small part of the problem. Learning to apply the system to specific problems and continuing to use it effectively depends on the continuing access of the less experienced institutions to highly skilled consultants who understand the quiddities of hardware and software and who can help the user recognize and surmount his difficulties as he attempts more sophisticated and varied applications on his campus.

Even in a centralized, single machine installation, this essential service cannot be neglected if progress is to be made. In the dispersed, complex, multi-machine community envisaged for this first major regional system, the provision of continuing dedicated and proficient support will be vital. It will also be expensive. In the early phases, about half of the effort of the Center must go into helping users apply the resources that are or will be made availble. As the system advances and takes on the appearance of greater homogeneity, less consulting will be needed. However, it is unlikely that this service can ever be reduced below one-third of the total effort. Thus, the Center contemplates the assumption of a continuing educational, training and consulting function of significant magnitude.

Bringing the effective use of computer based information systems to such a large group presents an outstanding opportunity. Because of the newness and great undeveloped scope of this field, almost all who have learned computing so far have learned it haphazardly. As a result, the industry is burdened with the load of a long series of historical accidents. New people should not have to repeat these mistakes. An expected major benefit of the proposed resource sharing effort should be a substantial improvement in the way we teach, undertake and share the benefits of applied computing science.

The entire field -- industry as well as government and education -- will benefit. Virtually all who will be using computers in the late 1970's have not even begun to think about the implications and potentialities to result from the intrusion of the computer and the exploitation of the computer sciences in higher education. If they can be given appropriate and stimulating exposure as suggested immediately above, many of today's most vexing problems (such as many associated with the lack of machine compatibility) could simply disappear.

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4. George W. Brown, James G. Miller and Thomas A. Keenan. Edunet: Report of the Summer Study on Information Networks. Wiley & Sons, New York. 1967.

5. EDUCOM. Interuniversity Communications Council, Ann Arbor, Michigan. January 1966, et seq.

Appendix 1

TWENTY-NINE RESOURCE SHARING EXPERIMENTS

PROJECT	INSTITUTIONS	
Library Computer Project	Yale University	Columbia University (main division)
Regional Computer Project Amount of Grant: $132,100 Funding Source: National Science Foundation	St. Anselm's College(NH) New England College(NH) Rivier College(NH)	Mt. St. Mary's College(NH) Notre Dame College(NH)
Regional Computer Project Principal Investigator: Dartmouth College Amount of Grant: $164,200 Funding Source: National Science Foundation	Dartmouth College(NH) Berkshire Community College(Mass) Bowdoin College(Maine) Middlebury College(Vt) New England College(NH) Vermont Technical College	Bates College(Maine) Colby Jr. College(NH) Mt. Holyoke College(Mass) Univ. of Vermont
University Information Technology Corporation Principal Investigator: Carl F. J. Overhage, M.I.T.	Harvard University	Massachusetts Institute of Technology
NERComP - New England Regional Computing Program (continued on next page)	Amherst College Babson Institute Bennington College Boston College Bowdoin College University of Bridgeport Cardinal Cushing College Colby College Suffolk University St. Anselm's College	Atlantic Union College Bates College Bentley College Boston University Brandeis University Brown University Clark University Connecticut College Mass. Inst. of Technology

PROJECT	INSTITUTIONS
Cooperating Institutions of New England Regional Computing Program (continued) Principal Investigator: Prof. P.M. Morse, M.I.T. Amount of Grant: $225,000 Funding Source: National Science Foundation	Univ. of Connecticut Dartmouth College Eastern Nazarene Col. Emmanuel College Goddard College Gordon College Univ. of Hartford Harvard University Col. of the Holy Cross Lesley College Lowell Tech. Inst. Univ. of Maine Univ. of Mass-Amherst Univ. of Mass-Boston Merrimack College Middlebury College Mt. Holyoke College Univ. of New Hampshire Northeastern Univ. Norwich University Providence College Regis College Rensselaer Polytechnic Inst. of Conn., Inc. Rhode Island College Rhode Island School of Design Univ. of Rhode Island Salve Regina College Simmons College Smith College Southeastern Massachusetts Technological Inst. Springfield College State College at Boston State Col. at Worcester Trinity College Tufts University U.S. Coast Guard Academy Univ. of Vermont Wellesley College Wesleyan College Western New England Col. Wheaton College Williams College Worcester Foundation for Experimental Biology Worcester Poly. Inst. Yale University
New England Land-Grant Network (New England Center) Amount of Grant: $1,800,000 Funding Source: W.K. Kellogg Foundation	Univ. of Connecticut Univ. of Maine Univ. of Massachusetts Univ. of New Hampshire Univ. of Rhode Island University of Vermont
Regional Computer Project Principal Investigator: Cornell University Amount of Grant: $116,800 Funding Source: National Science Foundation	Cornell University Eisenhower College Elmira College Ithaca College Keuka College Wells College Plus seven secondary schools

PROJECT	INSTITUTIONS	
Multi-Campus Regional Computing Center State University of New York	State Univ. Col-Brockport State Univ. Col-Fredonia Erie County Tech. Inst. Monroe Community Col.	State Univ. Col-Buffalo State Univ. Col-Geneseo Jamestown Community Col. Niagara Community College

Principal Investigators:
Richard Lesser, State University College-Buffalo
Anthony Ralston, State University College-Buffalo
Funding Source:
State University of New York

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Regional Computing Center	Alderson-Broaddus Col.(WVa) Davis & Elkins Col.(WVa) Geneva College(Pa) St. Vincent College Washington & Jefferson Col. Plus seven secondary schools	Chatham College(Pa) Duquesne University Point Park College(Pa) Seton Hall College Waynesburg College

Principal Investigator:
Thomas P. Cunningham at Carnegie-Mellon University, Pittsburgh
Amount of Grant:
$525,000
Funding Source:
National Science Foundation

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Three University Computing Center	University of North Carolina North Carolina State University Duke University

Principal Investigators:
Frederick P. Brooks, University of North Carolina
James K. Ferrell, North Carolina State University
Thomas M. Gallie, Duke University
Amount of Grant:
$1,500,000 (3 years)
Funding Source:
National Science Foundation and individual campuses

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North Carolina Computer Orientation Project	30 Colleges in North Carolina

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PROJECT	INSTITUTIONS	
West Virginia Computer Network Principal Investigator: Ernest L. Jores, University of West Virginia	Colleges, Universities and High Schools in West Virginia	
Total Systems Approach	Alabama State College Tuskegee Institute	Auburn University University of Alabama
Regional Computer Project Amount of Grant: $597,000 Funding Source: National Science Foundation	Southern Regional Educational Board(Ga) Loyola College Wofford College(SC) Eastern Mennonite Col(Va) George Peabody Col(Tenn) Plus 5 Universities making up Atlanta University Center Corporation	 Maryville College(Tenn) Centenary College(La) Fairmont State College(WVa) Xavier University
Regional Computer Project Amount of Grant: $427,900 Funding Source: National Science Foundation	Purdue University DePauw University Manchester College St. Joseph's College Plus 4 remote Purdue campuses and 4 secondary schools	Ball State University Hanover College Rose Polytechnic Institute Wabash College
Dayton-Miami Valley Consortium	Air Force Inst. of Tech. Cedarville College University of Dayton Urbana College Wilmington College Wright State University	Antioch College Central State University Sinclair Community Col. Wilberforce University Wittenberg University
Regional Computer Project Amount of Grant: $616,000 Funding Source: National Science Foundation	Illinois Inst. of Tech. Dominican College(Wisc) Loyola University Mundelein College Ripon College	Chicago City College Elmhurst College Monmouth College Quincy College St. Xavier College

PROJECT	INSTITUTIONS
Regional Computer Network Iowa-Illinois Amount of Grant: $581,700 Funding Source: National Science Foundation	University of Iowa Coe College Marycrest College St. Ambrose College Clark College Loras College Grinnell College Iowa Wesleyan Central College Augustana College Area 10 Community College
Integrated Computer System	Museum of New Mexico New Mexico Military Inst. Eastern New Mexico Univ. New Mexico Highlands Univ. New Mexico Institute of Mining & Technology New Mexico State Univ. Univ. of New Mexico Western New Mexico Univ.
Computing Centers Utilization	Kansas State University of Agriculture and Applied Science University of Kansas
Multiple College Accounting System	Parsons College Midwestern College Hiram Scott College
Pacific Northwest Computer Center	University of Alaska University of Idaho Montana State Univ. Oregon State University Skagit Valley College Central Washington State Col. Gonzaga University Pacific Lutheran Univ. Seattle University Univ. of Washington Walla Walla College Washington State University West Washington St. Col. Univ. of British Columbia Whitman College
Western Data Processing Center (continued on next page)	University of Alaska Arizona State University University of Arizona Calif. State Col-Fullerton Calif. Institute of Tech. Calif. Lutheran College Calif. Maritime Academy Chico State College Fresno State College Humboldt State College Sacramento State College Calif. State Col-Hayward Calif. State Col-Long Beach Calif. State Col-L.A.

PROJECT	INSTITUTIONS	
Western Data Processing Center (continued)	Calif. State Poly. College	Immaculate Heart College
	San Diego State College	San Fernando Valley St. Col.
	San Francisco State Co.	San Jose State College
	Chapman College	La Sierra College
	Claremont Graduate School and University Center	
	Loma Linca University	Mt. St. Marys College
	Pacific Union College	Pasadena College
	Pepperdine College	Pomona College
	Stanford University	Univ. of Calif-Berkeley
	Univ. of Calif.-Medicine	Univ. of Calif-Davis
	Univ. of Calif-Irvine	Univ. of Calif-L.A.
	Univ. of Calif-Riverside	Univ. of Calif-San Diego
	Univ. of Calif-San Francisco	Univ. of the Pacific
	Univ. of Calif-Santa Barbara	Univ. of the Redlands
	Univ. of San Francisco	Univ. of Santa Clara
	Univ. of Southern Calif.	West Coast University
	Whittier College	Colorado School of Mines
	Colorado State College	Colorado State University
	Fort Lewis College	Univ. of Colorado
	University of Denver	University of Hawaii
	College of Idaho	Idaho State University
	University of Idaho	Loyola University
	Montana State University	University of Montana
	University of Nevada	New Mexico Highlands Univ.
	New Mexico State Univ.	University of New Mexico
	Oregon State University	Pacific University
	Portland State College	Reed College
	University of Oregon	University of Portland
	Brigham Young University	University of Utah
	Utah State University	Weber State College
	Westminster College	Central Washington St. Col.
	Gonzaga University	Eastern Washington St. Col.
	Pacific Lutheran Univ.	Seattle Pacific College
	Seattle University	Univ. of Puget Sound
	University of Washington	Walla Walla College
	Washington State Univ.	Western Washington St. Col.
	Whitman College	University of Wyoming
	U.S. Air Force Academy	U.S. Naval Postgraduate Sch.
	Univ. of British Columbia	National Univ. of Mexico

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PROJECT	INSTITUTIONS
Regional Computer Project Amount of Grant: $243,700 Funding Source: National Science Foundation	Stanford University Calif. State College Mills College San Francisco State College University of San Francisco Plus 1 secondary school
Regional Computer Project Principal Investigator: Oregon State University Amount of Grant: $454,500 Funding Source: National Science Foundation	Oregon State University Easter College Lane Community College Oregon College of Education Oregon Tech. Inst. Portland State College
ARPA Network Funding Source: Advanced Research Project Agency	Stanford Research Inst. University of Calif-L.A. Univ. of Calif-Santa Barbara University of Utah
Regional Cooperative Project Western Interstate Commission for Higher Education for Management Information (WICHE) Principal Investigator: W. John Minter, WICHE Amount of Grant: $1,112,207	Stanford University Foothill Junior College Univ. of California California State Colleges Peralta Colleges University of Colorado Colorado College University of Idaho University of Hawaii New Mexico State University Univ. of New Mexico University of Utah Oregon State System of Higher Education Seattle University Seattle Community College Univ. of Washington Washington State Univ. Western Washington State College Central Washington State College Eastern Washington State College University of Wyoming University of Nevada

PROJECT	INSTITUTIONS	
Time-sharing Systems for Colleges and Universities in Oregon	Colleges and Universities in the Oregon State System for Higher Education	

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PROJECT	INSTITUTIONS	
EDUCOM Interuniversity Com- Communications Council	University of Akron	University of Alabama
	University of Alberta	University of Arizona
	Boston University	Univ. of British Columbia
	Brown University	Bucknell University
	University of Calgary	University of California
		Carnegie-Mellon University
	Cleveland State Univ.	University of Colorado
	Cornell University	Dartmouth College
	University of Dayton	Drexel Inst. of Technology
	Duke University	Emory University
	University of Florida	Florida State University
	Georgia Inst. of Tech.	University of Georgia
	Grand Valley State Col.	University of Illinois
	Indiana University	University of Iowa
	Johns Hopkins Univ.	University of Kansas
	Kent State University	King's College
	Lehigh University	Marquette University
	University of Maryland	Univ. of Massachusetts
	University of Miami	University of Michigan
	Michigan State College	Minnesota State College Board
	Univ. of Minnesota	University of Missouri
	Univ. of New Hampshire	University of New Mexico
	New York Inst. of Tech.	University of North Carolina
	New York University	State University of New York
	Northeastern University	North Carolina Res. Triangle
	Northwestern University	University of Notre Dame
	Ohio State University	University of Oregon
	Univ. of Pennsylvania	Pennsylvania State University
	Univ. of Pittsburgh	Polytechnic Inst. of Brooklyn
	Purdue University	University of Rochester
	Rose Polytechnic Inst.	Temple University
	Texas A&M University	Tufts University
	Tulane University	Vanderbilt University
	Medical College of Va.	University of Virginia
	Washington University of St. Louis	
	Univ. of Washington	Washington State University
	Wayne State University	Webster College
	Western Reserve Univ.	University of Wisconsin

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Appendix 2

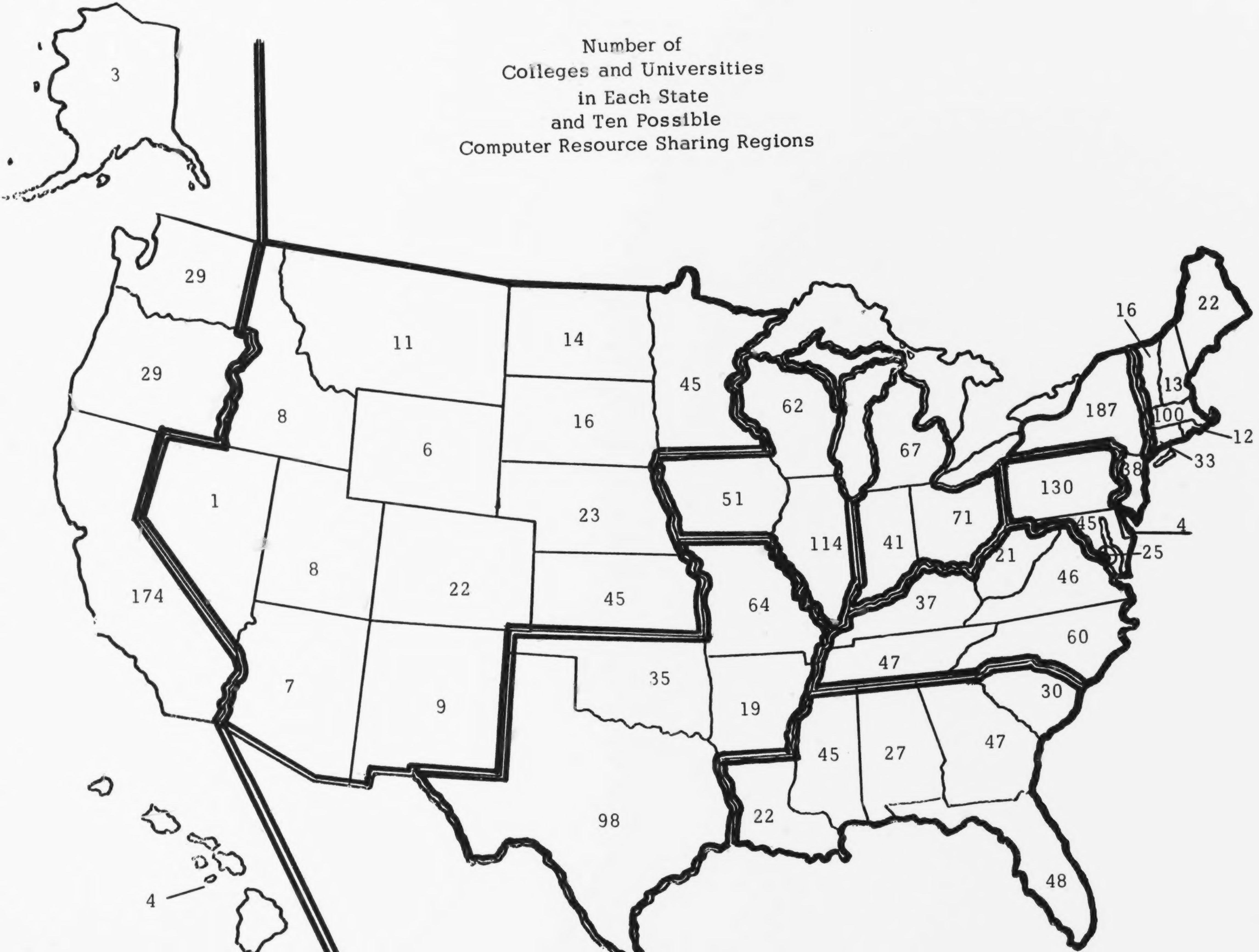
TEN CONTIGUOUS REGIONS

Each Containing About 200 Colleges and Universities

NEW ENGLAND		196
Connecticut	33	
Maine	22	
Massachusetts	100	
New Hampshire	13	
Rhode Island	12	
Vermont	16	
NEW JERSEY and NEW YORK		225
New Jersey	38	
New York	187	
MID ATLANTIC		204
Delaware	4	
District of Columbia	25	
Maryland	45	
Pennsylvania	130	
EASTERN		211
Kentucky	37	
North Carolina	60	
Tennessee	47	
Virginia	46	
West Virginia	21	
SOUTHEASTERN		219
Alabama	27	
Florida	48	
Georgia	47	
Louisiana	22	
Mississippi	45	
South Carolina	30	

EAST CENTRAL		179
Michigan	67	
Ohio	71	
Indiana	41	
WEST CENTRAL		227
Illinois	114	
Iowa	51	
Wisconsin	62	
SOUTH CENTRAL		216
Arkansas	19	
Missouri	64	
Oklahoma	35	
Texas	98	
WESTERN		215
Arizona	7	
Colorado	22	
Idaho	8	
Kansas	45	
Minnesota	45	
Montana	11	
Nebraska	23	
Nevada	1	
New Mexico	9	
North Dakota	14	
South Dakota	16	
Utah	8	
Wyoming	6	
PACIFIC		239
Alaska	3	
California	174	
Hawaii	4	
Oregon	29	
Washington	29	

Number of
Colleges and Universities
in Each State
and Ten Possible
Computer Resource Sharing Regions


3
29
29
174
8
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11
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14
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23
45
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64
19
22
62
114
67
41
71
37
47
45
27
47
30
60
46
21
45
130
187
38
4
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16
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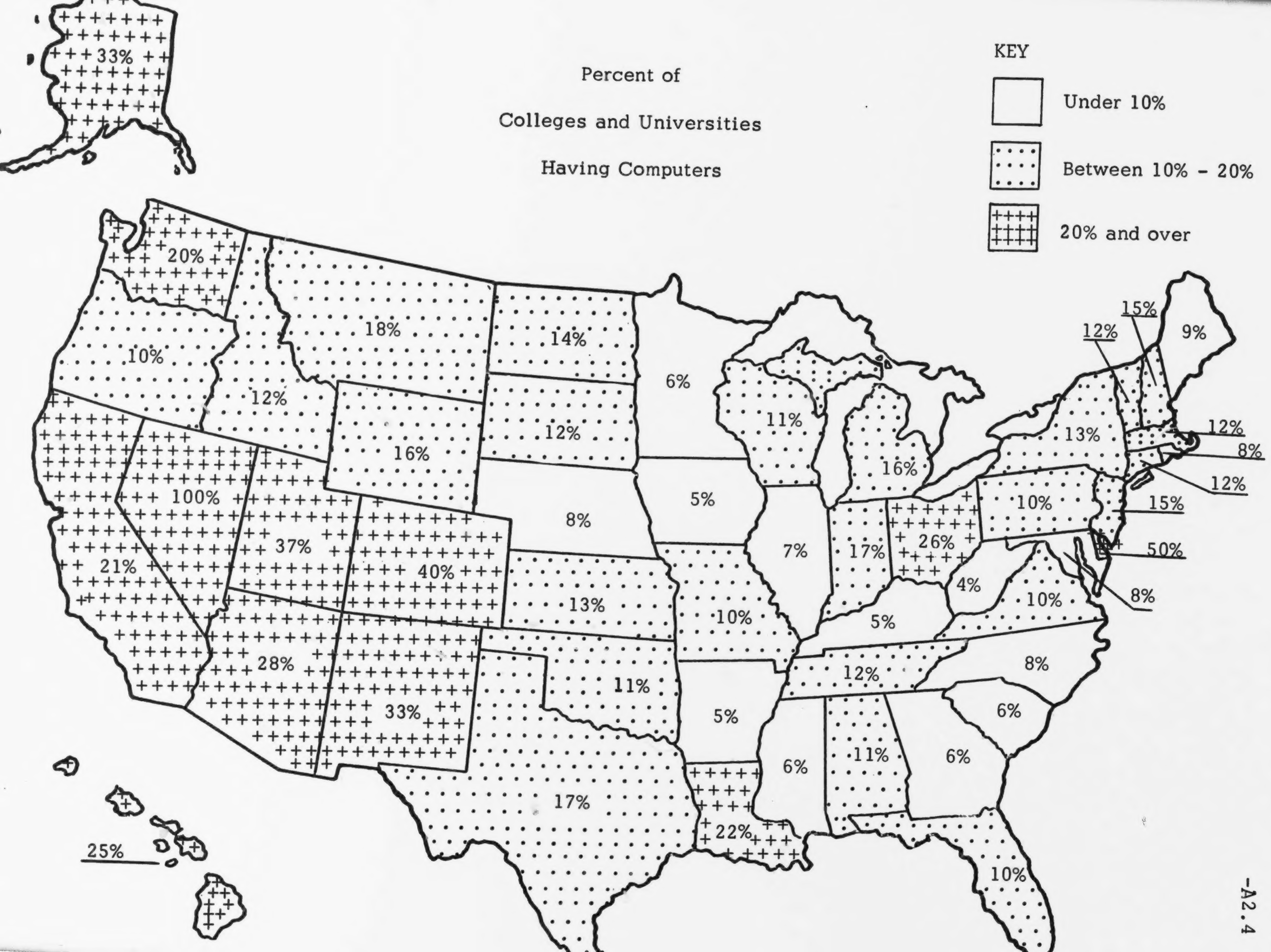
100
22
12
33
48
4

Percent of

Colleges and Universities

Having Computers


KEY
Under 10%
Between 10% - 20%
20% and over
33%
20%
10%
12%
18%
14%
6%
11%
16%
13%
9%
15%
12%
12%
8%
12%
15%
50%
8%
21%
100%
37%
40%
16%
12%
8%
5%
7%
17%
26%
10%
4%
10%
13%
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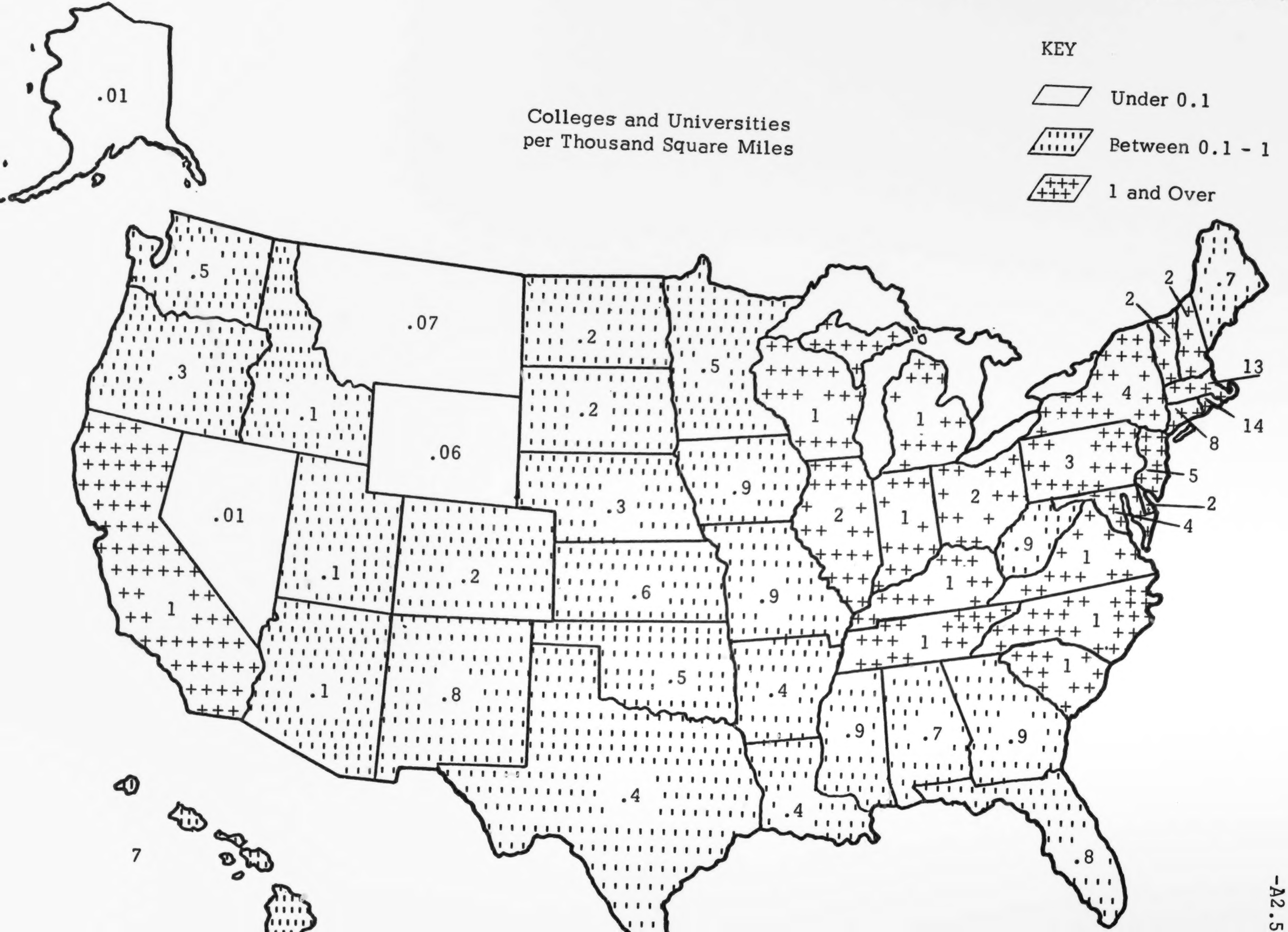
6%
11%
6%
10%
25%



Colleges and Universities per Thousand Square Miles

KEY
Under 0.1
Between 0.1 - 1
1 and Over
.01
.5
.3
.07
.1
.06
.01
1
.1
.2
.1
.8
.2
.2
.3
.6
.5
.4
.5
.9
.9
.4
.4
1
1
2
1
1
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.7
.9
.8
2
1
1
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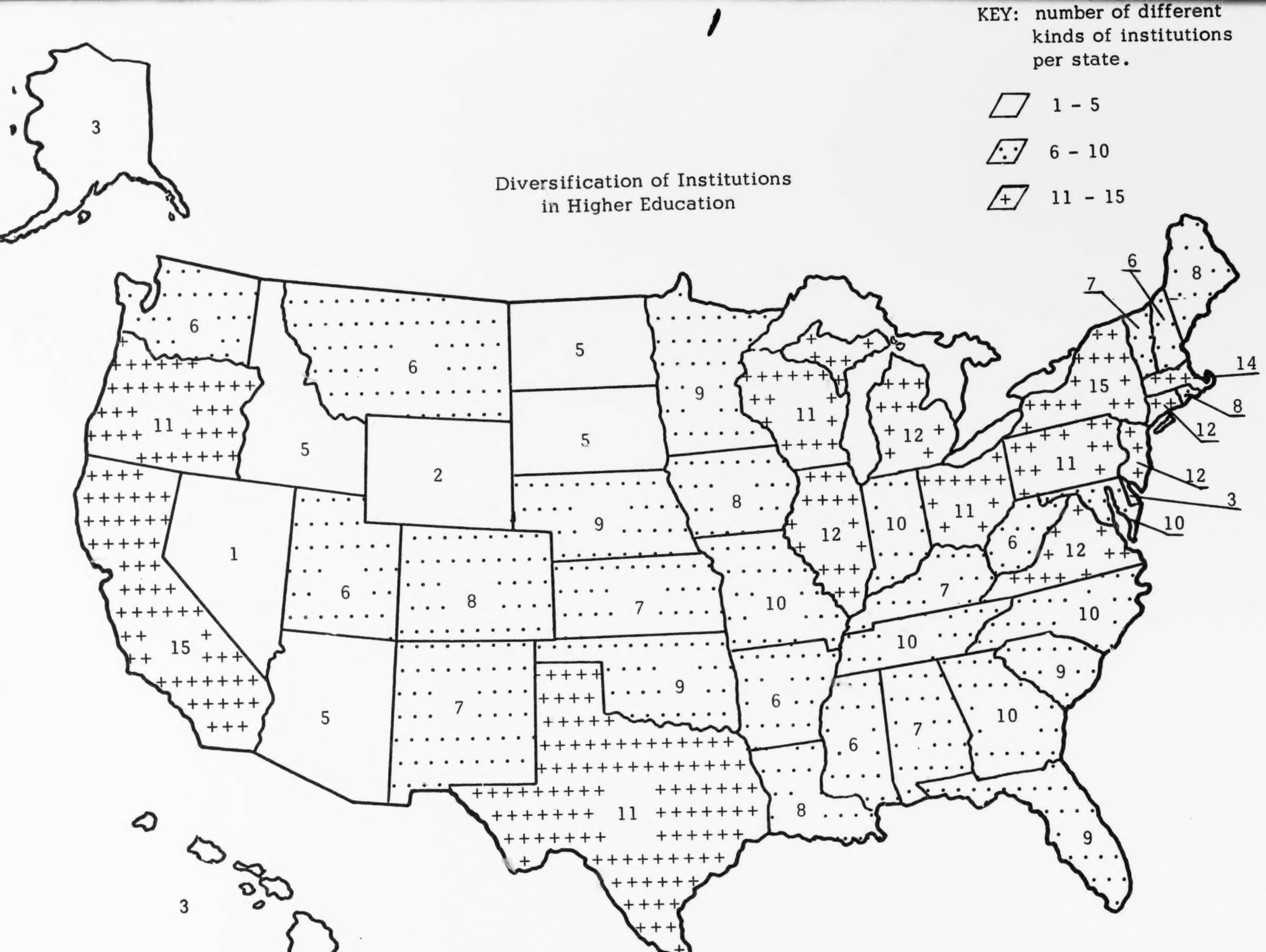
5
2
4
7

Diversification of Institutions in Higher Education


KEY: number of different kinds of institutions per state.
1 - 5
6 - 10
11 - 15
3
6
11
15
1
5
6
5
2
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7
5
5
9
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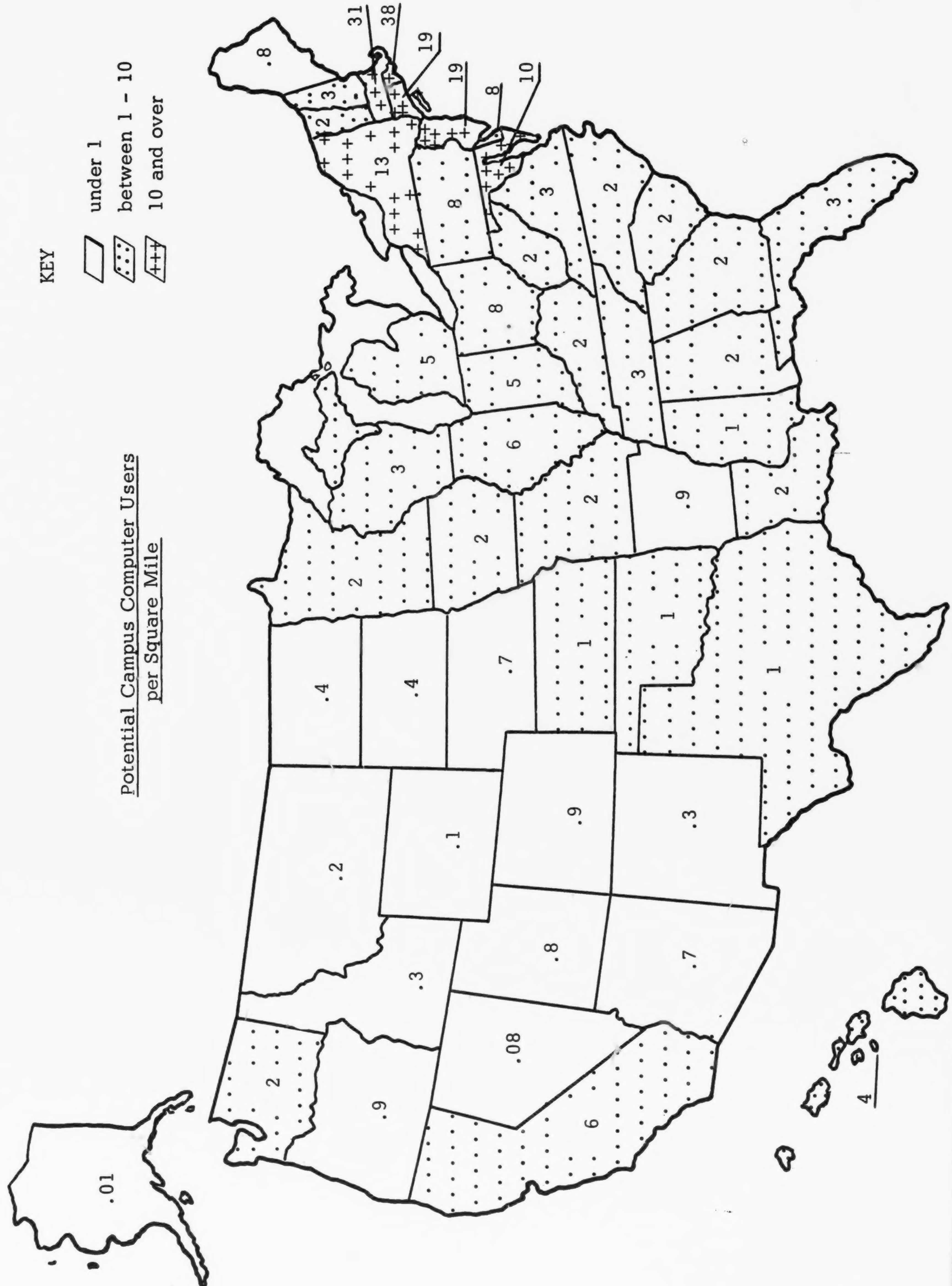

Potential Campus Computer Users per Square Mile

KEY
under 1
between 1 - 10
10 and over
.01
4
2
.9
6
.08
.3
.2
.1
.8
.7
.9
.3
.4
.4
.7
1
1
1
2
2
2
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2
3
6
5
5
1
8
2
2
3
2
3
2
2
3
2
8
13
2
3
.8
31
38
19
19
8
10

Appendix 3

Institutions of Higher Education in New England

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
CONNECTICUT						
Albertus Magnus C. New Haven	RC	F	B	602	N	N
Annhurst C. Woodstock	RC	F	B	330	N	N
Berkeley Divinity S. New Haven	PE	M	M	86	N	N
Bridgeport Engr. Inst. Bridgeport	P	C	B	512	N	N
Central Conn. St. C. New Britian	St	C	M	7046	N	N
C. Notre Dame Wilton	RC	F	B	143	N	N
Conn. College New London	P	F	M	1543	Y	N
Danbury St. C. Danbury	St	C	M	2195	N	N
Diocesan Sisters C. Bloomfield	RC	F	B	180	N	N
Fairfield U. Fairfield	RC	M	M	2294	N	Y
Hartford C. for Women Hartford	P	F	A	198	N	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Connecticut (continued)						
Hartford Sem. Found. Hartford	I	C	B	158	N	N
Hartford St. Tech. Inst. Hartford	St	C	A	344	N	N
Holy Apostles Sem. Cromwell	RC	M	B	140	N	N
Holy Family Sem. West Hartford	RC	M	A	63	N	N
Manchester Comm. C. Manchester	C	C	A	447	N	N
Mitchell C. New London	P	C	A	1550	N	N
Morse C. Hartford	J	C	A	314	N	N
Mt. Sacred Heart C. Hamden	RC	F	A	47	N	N
New Haven C. West Haven	P	C	B	2673	N	N
Norwalk Comm. C. Norwalk	C	C	A	1239	N	N
Norwalk St. Tech. Inst. South Norwalk	St	C	A	1310	N	N
Our Lady of the Angels Jr. C. Enfield	RC	F	A	40	N	N
Post Jr. C. Waterbury	P	C	A	350	N	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Connecticut (continued)						
Quinnipiac C. Hamden	P	C	B	2309	N	N
Sacred Heart U. Bridgeport	RC	C	B	1494	N	N
Saint Alphonsus C. Suffield	RC	M	B	90	N	N
Saint Basil's C. Stamford	RC	F	B	33	N	N
Saint Joseph C. West Hartford	RC	F	M	781	N	N
Saint Mary's Sem. Norwalk	RC	M	B	21	N	N
Saint Thomas Sem. Bloomfield	RC	M	A	161	N	N
Seat of Wisdom C. Litchfield	RC	F	B	107	N	N
Silvermine C. of Art New Canaan	P	C	A	380	N	N
So. Conn. St. C. New Haven	St	C	M	6506	N	N
Thames Valley St. Tech. Inst. Norwich	St	C	A	261	N	N
Trinity C. Hartford	P	M	M	1671	Y	Y
U.S. Coast Guard A. New London	N	M	B	687	Y	N
U. of Bridgeport Bridgeport	P	C	M	7938	Y	Y

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Connecticut (continued)						
U. of Conn. Storrs	St	C	P	15223	Y	Y
U. of Hartford West Hartford	P	C	M	11222	Y	N
Waterbury St. Tech. Inst. Waterbury	St	C	A	760	N	N
Wesleyan U. Middletown	P	M	P	1455	Y	Y
Willimantic St. C. Willimantic	St	C	M	1440	N	N
Yale U. New Haven	P	M	P	8575	Y	Y
MAINE						
Aroostook St. C. Presque Isle	St	C	B	351	N	N
Auburn Maine S. of Commerce Auburn	Pr	C	A	106	N	N
Bangor Th. Sem. Bangor	P	C	B	116	N	N
Bates C. Lewiston	P	C	B	900	Y	N
Bliss C. Lewiston	P	C	A	163	N	N
Bowdoin C. Brunswick	P	M	M	891	Y	N
Colby C. Waterville	P	C	M	1450	Y	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Maine (continued)						
Farmington St. C. Farmington	St	C	M	615	N	N
Fort Kent St. C. Fort Kent	St	C	B	222	N	N
Gorham St. C. Gorham	St	C	M	1358	N	N
Husson C. Bangor	P	C	B	1211	N	N
Maine Maritime A. Castine	St	M	B	490	N	N
Nasson C. Springvale	P	C	B	615	N	N
N. Cons. of Music Bangor	P	C	B	67	N	N
Oblate C. and Sem. Bar Harbor	RC	M	A	27	N	N
Ricker C. Houlton	B	C	B	725	N	N
Saint Francis C. Biddeford	RC	M	B	439	N	N
Saint Joseph's C. North Windham	RC	F	B	387	N	N
Thomas C. Waterville	P	C	B	411	N	N
U. of Maine Orono	St	C	P	11755	Y	Y
Washington St. C. Machias	St	C	B	304	N	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Maine (continued)						
Westbrook Jr. C. Portland	P	F	B	396	N	N
MASSACHUSETTS						
Am. Int. C. Springfield	P	C	M	3402	N	N
Amherst C. Amherst	P	M	M	1206	Y	Y
Andover Newton Th. S. Newton Center	P	C	M	368	N	N
Anna Maria C. for Women Paxton	RC	F	B	519	N	N
Aquinas S. Milton	RC	F	A	200	N	N
Assumption C. Worcester	RC	M	M	1215	N	N
Atlantic Union C. South Lancester	S	C	B	798	Y	N
Babson Inst. of Bus. Adm. Babson Park	P	M	M	1010	Y	Y
Bay Path Jr. C. Longmeadow	P	F	A	437	N	N
Becker Jr. C. Worcester	P	C	A	635	N	N
Bentley C. of Acct & Fin Boston	P	C	B	4227	Y	N
Berkshire Christian C. Lenox	A	C	B	135	N	N

Name and Location	Control	Student body	Highest Degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
Berkshire Comm. C. Pittsfield	St	C	A	1289	N	N
Boston C. Chestnut Hill	RC	C	P	9526	Y	Y
Boston Cons. of Music Boston	P	C	M	366	N	N
Boston U. Boston	P	C	P	22382	Y	Y
Bradford Jr. C. Bradford	P	F	A	423	N	N
Brandeis U. Waltham	P	C	P	2090	Y	Y
Bryant & Stratton Cmrcl S. Boston	Pr	C	A	1570	N	N
Burdett C. Boston	Pr	C	A	1364	N	N
Cambridge Jr. C. Cambridge	P	C	A	96	N	N
Cambridge S. of B. Boston	Pr	C	A	552	N	N
Cape Cod Comm. C. Hyannis	St	C	A	728	N	N
Cardinal Cushing C. Brookline	RC	F	B	329	Y	N
Clark U. Worcester	P	C	P	2334	Y	Y
C. of the Holy Cross Worcester	RC	M	M	2094	Y	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
C. of Our Lady Chicopee	RC	F	B	925	N	N
C. of the Sacred Hearts Fall River	RC	F	B	381	N	N
Curry C. Milton	P	C	M	570	N	N
Dean Jr. C. Franklin	P	C	A	969	N	N
E. Nazarene C. Wollaston	Nz	C	B	845	Y	N
Emerson C. Boston	P	C	M	1054	N	N
Emmanuel C. Boston	RC	F	M	1329	Y	N
Endicott Jr. C. Beverly	P	F	A	733	N	N
Episcopal Th. S. Cambridge	PE	C	B	129	N	N
Fisher Jr. C. Boston	P	F	A	507	N	N
Forsyth S. for Den. Hygnts Boston	P	F	A	193	N	N
Franklin Inst. of Boston Boston	C	C	A	903	N	N
Garland Jr. C. Boston	P	F	A	378	N	N
Gordon C. Wenham	P	C	B	828	Y	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
Greek Archdiocese Holy Cross Orthodox Th. S. Brookline	G	M	B	100	N	N
Greenfield Comm. C. Greenfield	St	C	A	635	N	N
Harvard U. Cambridge	P	M	P	13411	Y	Y
Hebrew Teachers C. Brookline	P	C	M	165	N	N
Holyoke Comm. C. Holyoke	C	C	A	1701	N	N
Lasell Jr. C. Auburndale	P	F	A	721	N	N
Leicester Jr. C. Leicester	P	M	A	238	N	N
Lesley C. Cambridge	P	C	M	647	Y	N
Lowell Tech. Inst. Lowell	St	C	P	4377	Y	Y
Marist C. and Sem. Framingham Centre	RC	M	B	86	N	N
Mass. Bay Comm. C. Watertown	St	C	A	1213	N	N
Mass. C. of Art Boston	St	C	B	499	N	N
Mass. C. of Optometry Boston	P	C	B	160	N	N
Mass. C. of Pharmacy Boston	P	C	P	664	N	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
Mass. Inst. of Tech. Cambridge	P	C	P	7408	Y	Y
Mass. Maritime A. Buzzards Bay	St	M	B	211	N	N
Merrimack C. North Andover	RC	C	B	2207	Y	N
Mt. Alvernia C. Newton	RC	F	B	88	N	N
Mt. Holyoke C. South Hadley	P	F	M	1748	Y	N
Mt. Ida Jr. C. Newton Centre	P	F	A	626	N	N
Mt. Wachusett Comm. C. Gardner	St	C	A	447	N	N
New England Cons. of Music Boston	P	C	M	372	N	N
Newton C. of the Sacred Heart Newton	RC	F	B	730	N	N
Newton Jr. C. Newtonville	C	C	A	639	N	N
Nichols C. of Bus. Adm. Dudley	P	M	B	663	N	N
North Shore Comm. C. Beverly	St	C	A	1480	N	N
Northampton Comrcl C. Northampton	Pr	C	A	580	N	N
Northeastern U. Boston	P	C	P	29131	Y	Y

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
N. Essex Comm. C. Haverhill	D	C	A	719	N	N
Perry Normal S. Boston	P	F	A	134	N	N
Pine Manor Jr. C. Chestnut Hill	P	F	A	348	N	N
Queen of Apostles C. & Sem. Dedham	RC	M	B	52	N	N
Quincy Jr. C. Quincy	C	C	A	1072	N	N
Quinsigamond Comm. C. Worcester	St	C	A	767	N	N
Radcliffe C. Cambridge	P	F	B	1191	N	N
Regis C. Weston	RC	F	B	1260	Y	N
Saint Columban's C. & Sem. Milton	RC	M	B	22	N	N
Saint Hyacinth C. & Sem. Granby	RC	M	B	70	N	N
Saint John's Sem. Brighton	RC	M	M	375	N	N
Saint Stephen's C. Dover	RC	M	P	53	N	N
Simmons C. Boston	P	F	M	1975	Y	N
Smith C. Northampton	P	F	P	2322	Y	Y

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
Southeastern Mass. Tech. Inst. North Dartmouth	St	C	M	3370	Y	Y
Springfield C. Springfield	P	C	P	2045	Y	N
St. C. at Boston Boston	St	C	M	5533	Y	N
St. C. at Bridgewater Bridgewater	St	C	M	4388	N	N
St. C. at Fitchburg Fitchburg	St	C	M	2164	N	N
St. C. at Framingham Framingham	St	C	B	1896	N	N
St. C. at Lowell Lowell	St	C	B	1083	N	N
St. C. at North Adams North Adams	St	C	M	1017	N	N
St. C. at Salem Salem	St	C	M	4507	N	N
St. C. at Westfield Westfield	St	C	M	2107	N	N
St. C. at Worcester Worcester	St	C	M	2214	Y	N
Stevens B. C. Fitchburg	P	C	A	148	N	N
Stonehill C. North Easton	RC	C	B	1213	N	N
Suffolk U. Boston	P	C	M	2872	Y	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Massachusetts (continued)						
Tufts U. Medford	P	C	P	5015	Y	Y
U. of Mass Amherst	St	C	P	10832	Y	Y
Wellesley C. Wellesley	P	F	M	1765	Y	Y
Wentworth Inst. Boston	P	M	A	2574	N	N
W. New England C. Springfield	P	C	M	2112	Y	Y
Wheaton C. Norton	P	F	B	1090	Y	N
Wheelock C. Boston	P	F	M	489	N	N
Williams C. Williamstown	P	M	M	1310	Y	N
Woods Hole Oceangraphic Institute Woods Hole	P	C	P	7	N	N
Worcester Jr. C. Worcester	P	C	A	2768	N	N
Worcester Polytechnic Inst. Worcester	P	M	P	1643	Y	Y
NEW HAMPSHIRE						
Belknap C. Center Harbor	P	C	B	350	N	N
Colby Jr. C. for Women New London	P	F	B	604	N	N
Dartmouth C. Hanover	P	M	P	3688	Y	Y

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
New Hampshire (continued)						
Franconia C. Franconia	P	C	A	194	N	N
Franklin Pierce C. Rindge	P	C	B	487	N	N
Keene St. C. Keene	St	C	M	1828	N	N
Mt. Saint Mary C. Hooksett	RC	F	B	303	N	N
Nathaniel Hawthorne C. Antrim	P	C	B	425	N	N
New England C. Henniker	P	C	B	739	N	N
New Hampshire C. of Actg. & Commerce Manchester	Pr	C	B	1125	N	N
New Hampshire Voc. Inst. Manchester	St	C	A	232	N	N
New Hampshire Voc. Inst. Portsmouth	St	C	A	153	N	N
Notre Dame C. Manchester	RC	F	B	329	N	N
Plymouth St. C. Plymouth	St	C	M	1546	N	N
Queen of Peace Mission Sem. Jaffrey Center	RC	M	B	83	N	N
Rivier C. Nashua	RC	F	M	672	N	N
Saint Anselm's C. Manchester	RC	M	B	1429	Y	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
New Hampshire (continued)						
Saint Anthony Sem. Hudson	RC	M	B	49	N	N
U. of New Hampshire Durham	St	C	P	6957	Y	Y
RHODE ISLAND						
Barrington C. Barrington	P	C	B	653	N	N
Brown U. Providence	P	C	P	4808	Y	Y
Bryant C. Providence	P	C	B	2749	N	N
Catholic Teachers C. Providence	RC	F	B	652	N	N
Johnson and Wales Jr. C. of Business Providence	P	C	A	1225	N	N
Mt. Saint Joseph C. Wakefield	RC	F	B	85	N	N
Providence C. Providence	RC	M	P	3518	Y	Y
Rhode Island C. Providence	St	C	M	4257	Y	N
Rhode Island Jr. C. Providence	St	C	A	1186	N	N
Rhode Island S. of Design Providence	P	C	M	958	Y	N
Roger Williams Jr. C. Providence	P	C	A	908	N	N

Name and Location	Control	Student body	Highest degree	Enrollment	Member of NERComP	Computer(s) on campus
Rhode Island (continued)						
Salve Regina C. Newport	RC	F	B	776	Y	N
Sem. of Our Lady of Providence Warwick	RC	M	B	105	N	N
U. of Rhode Island Kingston	St	C	P	11861	Y	Y
VERMONT						
Bennington C. Bennington	P	F	M	385	Y	N
Castleton St. C. Castleton	St	C	B	747	N	N
Champlain C. Burlington	P	C	A	581	N	N
C. of Saint Joseph the Provider Rutland	RC	F	B	70	N	N
Goddard C. Plainfield	P	C	B	550	Y	N
Green Mountain C. Poultney	P	F	A	635	N	N
Johnson St. C. Johnson	St	C	B	472	N	N
Lyndon St. C. Lyndon Center	St	C	B	386	N	N
Marlboro C. Marlboro	P	C	B	140	N	N
Middlebury C. Middlebury	P	C	P	1414	Y	N

Name and Location	Control	Student Body	Highest Degree	Enrollment	Member of NERComP	Computer(s) on campus
Vermont (continued)						
Norwich U. Northfield	P	M	B	1221	Y	Y
Saint Michael's C. Winooski	RC	M	M	1294	N	N
Trinity C Burlington	RC	F	B	483	N	N
U. of Vermont and St. Agricultural C. Burlington	St	C	P	4463	Y	Y
Vermont C. Montpelier	P	F	A	515	N	N
Vermont Tech. C. Randolph Center	St	C	A	302	N	N
Windham C. Putney	P	C	B	397	N	N

Meaning of abbreviations:

Under "Name and Location":

A.	Academy
Adm.	Administration
Am.	American
B.	Business
C.	College
Comcrl	Commercial
Comm.	Community
Conn.	Connecticut
Cons.	Conservatory
E.	Eastern
Eng.	Engineering
Found.	Foundation
Inst.	Institute
Int.	International
Jr.	Junior
Mass.	Massachusetts
Mt.	Mount
N.	Northern
S.	School
So.	Southern
Sem.	Seminary
St.	State
Tech.	Technical
Th.	Theological
U.	University
U.S.	United States
W.	Western

Under "Control":

A	Adventist Christian Church
B	Baptist Church
C	County Government
D	District Government
G	Greek Orthodox Catholic Church
I	Interdenominational
J	Junior college of business
N	Federal government
Nz	Nazarene Church

Meaning of abbreviations (continued):

Under "Control":

P	Private
PE	Protestant Episcopal Church
Pr	Proprietary
RC	Roman Catholic Church
S	Seventh Day Adventist Church
St	State Government

Under "Student body":

C	Coeducational
F	Female students only
M	Male students only
S	Separate colleges for men and women

Under "Highest degree":

A	Associate (2 but less than 4 years)
B	Bachelor or first professional degree
M	Master or second professional degree
P	Doctor of Philosophy or equivalent

Sources:

Education Directory, 1966-1967. U.S. Dept. Health, Education and Welfare, Washington, D.C. 1967.

John W. Hamblen. Computers in Higher Education. Southern Regional Education Board, Atlanta, Ga. 1967

New England Institutional Representatives. March 1968

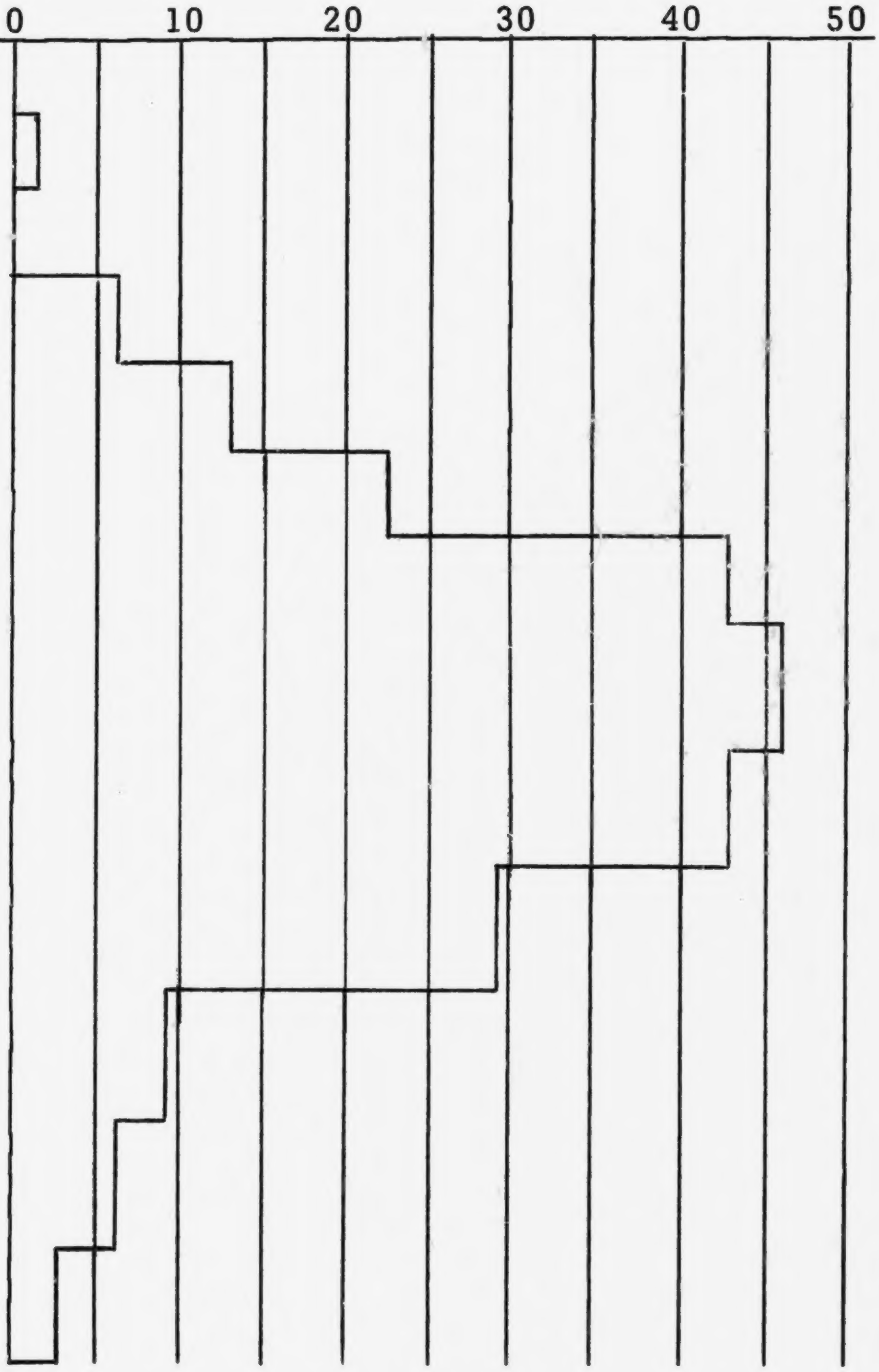
E.H. Goodman(ed.) Automated Education Handbook, Section 7. Automated Education Center, Detroit, Mich. 1965

Enrollment in New England's Institutions of Higher Education

	Conn.	Maine	Mass.	N. Hamp.	R.I.	Vermont	TOTAL
1 - 10	0	0	1	0	0	0	1
10 - 20	0	0	0	0	0	0	0
20 - 50	4	1	1	1	0	0	7
50 - 100	3	1	6	1	1	1	13
100 - 200	7	3	9	2	1	1	23
200 - 500	8	8	15	6	0	6	43
500 - 1,000	4	5	24	3	5	5	46
1,000 - 2,000	8	3	23	4	2	3	43
2,000 - 5,000	4	0	19	1	4	1	29
5,000 - 10,000	4	0	4	1	0	0	9
10,000 - 20,000	2	1	3	0	1	0	7
20,000 - 50,000	0	0	2	0	0	0	2
TOTAL	44	22	107	19	14	17	223

Illustration that Enrollment is Approximately Log-Normal Distributed

Enrollment	Number of Institutions
1-10	1
10-20	0
20-50	7
50-100	13
100-200	23
200-500	43
500-1,000	46
1,000-2,000	43
2,000-5,000	29
5,000-10,000	9
10,000-20,000	7
20,000-50,000	2



Computer Availability* in New England

	CONN.	MAINE	MASS.	N. HAMP.	R.I.	VERMONT	TOTAL
Number of Institutions	44	22	107	19	14	17	223
Number of Institutions with Computers	6	1	17	2	3	2	31
Percentage of Institutions with Computers	14%	5%	16%	11%	21%	12%	14%
Number of Students	84,918	22,999	214,503	21,192	33,741	14,055	391,408
Number of Students near Computers*	37,156	11,755	119,934	10,645	20,187	5,647	205,361
Percentage of Students near Computers*	44%	51%	51%	50%	60%	40%	53%
Number of Institutions belonging to NERComP	8	4	33	2	6	5	58
Percentage of Institutions belonging to NERComP	18%	18%	31%	11%	43%	29%	26%
Number of Students in NERComP member Institutions	48,314	14,996	141,799	10,645	26,178	8,033	249,965
Percentage of Students in NERComP member Institutions	57%	65%	66%	50%	78%	57%	64%

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* A computer is listed as being "available" if it is on the same campus as the potential user. This obviously does not imply that access to the computer is possible.

APPENDIX 4

COMPUTER RESOURCE SHARING AN APPROACH

Phase 1 - Establishing The Basic Service

Operational - 12th Month

The first step is to establish the basic service and acquire a facility and staff in a geographically strategic location.

Although the most skillful users will quickly adopt each new improvement as it becomes available, the needs of the more numerous smaller and newer users will require retention of the less advanced facilities of earlier phases throughout the project.

Tasks: An initial staff of 20 professional and 10 clerical people will perform the following:

1. Ascertain detailed requirements for computing service in the region.
2. Compile a catalog of rates of available hardware and software resources.
3. Establish a training program for people of the participating colleges and universities in the effective use of these resources.
4. Provide advisory and consulting services.
5. Transfer information between the users and available machines by courier, mail, bus, air and rail service.
6. Furnish centralized billing for computer time.

Equipment: The only hardware required initially will be for support services, such as card punching, for those schools which are not sufficiently involved to justify their own.

Phase 2 - Data-Phone Transmission

Operational - 24th Month

NEARS will next introduce the transfer of information via Data-Phone by providing Wide Area Telephone Service (WATS) both into and out of the Center. The user will dial the system on one of the incoming WATS lines and ask a human operator to connect him, through one of the outgoing WATS lines, to a specific installation.

Tasks:	Five additional professionals will be needed to help establish computer to Data-Phone interfaces plus five clerical people for manual inter-connection of the lines.
Equipment:	Estimated initial annual cost of Data-Phone rentals and toll charges is $100,000 with a growth of about 20% per year.

Phase 3 - Automated Switching

Operational - 36th Month

A computer will be procured and used to automate the connection of communication lines.

Tasks: Approximately ten man years of system programming effort will be required to make the communications processor operational. This work includes:

1. Establish system standards for automatic dial up procedures. (1 man year)
2. Program the communications controller to implement the standard procedures. (7 man years)
3. Validate the effectiveness of the system by experimental operation. (2 man years)

Equipment: $750,000 will be required for the communications processor.

Phase 4 - Store And Forward Capability

Operational - 48th Month

A store and forward message switching capability will be added to the communications processor in order to eliminate the inherent inefficiencies of direct line connection between outstations and processors. The user will then be able to dial the Center and leave a job for subsequent processing. As communication lines and the desired computer become available, the communications processor will forward this job to the computer, accept the results, then call up the originator of the problem and return them to him.

Tasks: Twenty man years of system programming will be required to:

1. Determine detailed characteristics of the various outstation and computer communication interfaces. (4 man years)
2. Program the communications processor to interface with each node of the system. (10 man years)
3. Design and implement automatic storage and retrieval procedures. (1 man year)
4. Design and implement call back procedures. (1 man year)
5. Validate the system by experimental operation. (4 man years)

Equipment: $500,000 will be required for secondary storage.

Upon completion of Phase 4, additional effort should be begun to make the advantages of NEARS available to other regions of the country. These additional costs are not included in this plan.

Phase 5 - Limited Inter-System Compatibility

Operational - 60th Month

Limited inter-system compatibility will be developed. For example, the communications processor will transliterate character codes from an outstation of one manufacturer so that they may be accepted by the computer of another. Work will begin on providing the more complete compatibility envisaged for Phase 7.

Tasks: Twenty-five man years will be required to complete the following tasks:

1. Establish a standard internal representation and conventions for transliteration between each type of station and the standard. (3 man years)
2. Program the communications processor to perform the various transliterations. (10 man years)
3. Validate the system by experimental operation. (5 man years)
4. In preparation for Phase 7, requirements and a preliminary design of a machine independent programming language will be established. (2 man years)
5. Design and implement experimental software support for building the machine independent language translators. (5 man years)

Equipment: $250,000 for upgraded processor capability.

Phase 6 - Automatic Load Sharing

Operational - 72nd Month

Automatic load sharing on a "let the buyer beware" basis will be introduced. In addition to being able to ask for service on a specific system, the user may now ask for the least expensive FORTRAN compile and run, for example, and the system will decide which specific equipment will be assigned. Hence, if the user is willing to write his programs in a manner that can be moved from machine to machine without difficulty, then he will not only get cheaper service, but the overall system load sharing should improve substantially.

Tasks: Thirty man years will be required for the following:

1. Design the brokerage algorithm. (1 man year)
2. Implement the algorithm on the communications processor. (5 man years)
3. Validate the system. (5 man years)
4. In preparation for Phase 7, coordinate the language design with the educational community and establish the final specifications. (5 man years)
5. Establish operational software support for building the language translators. (10 man years)
6. In preparation for Phase 8, determine requirements and establish a preliminary design for a machine independent operating system. (4 man years)

Equipment: None required

Phase 7 - Machine Independent Programming

Operational - 84th Month

Load sharing capabilities will next be improved through the introduction of machine independent programming languages. These will be implemented on the various systems in a unified compiler development which will insure that correct use of the specified language on any machine will produce the identical result.

Tasks:

1. Estimated cost is ten man years per language for the first machine using that language and five man years for subsequent machines using the same language. Anticipated initial demand is for one language on five distinct machines. (30 man years)
2. In preparation for Phase 8, coordinate the operating system design with the educational community and establish the final specifications. (5 man years)

Equipment: None required

Phase 8 - Machine Independent Operations

Operational - 96th Month

A system standard, machine independent operating system will be produced for each machine to permit effective shared storage and to expedite inter-machine communication.

Task:	Estimated cost for this task is twenty man years for the first machine and five man years for each subsequent machine. Anticipated demand is five distinct machines. (40 man years)
Equipment:	None required

Phase 9 - Central Shared Storage

Operational -108th Month

Tasks:

1. A central shared storage facility will be provided to minimize the cost of communication between or duplication of data at the several installations. (15 man years)
2. Two additional computers are expected for addition to the network. (10 man years)
3. Begin transfer of the facility to a group with primary emphasis on operating responsibility. (10 man years)

Equipment: $500,000 for tertiary storage.

Phase 10 - Improved Communications

Effective - 120th Month

Tasks:

1. A general upgrading and decentralization of the communications network will be carried out. This will make the system less dependent on the failure of the central communications controller. (15 man years)
2. Complete transfer of the facility to an operating group. (10 man years)

Equipment: An estimated $1,000,000 for decentralized communications processors.

Chapter VI

THE COMPUTER IN INSTRUCTION

A central function of colleges and universities is to provide an environment for learning. Little is known about how learning takes place, but research on the nature of the process is advancing in quality and scope. Educational systems are largely information systems. Advances in the information and computing sciences can be immensely important in understanding and improving the learning process; this research is accelerating at a rapid rate. The results suggest that computer-based systems can be of great assistance in instruction at all levels.

Objectives of the Educational Institution

The fundamental instructional goal of colleges and universities is to provide the best education each individual can use at the lowest possible cost. The information sciences can contribute to the realization of this high aspiration, but the applications must be designed within realistic constraints. The cost of new developments must be kept within the limits of available funds, operating costs must be economically feasible and more efficient use must be made of each institution's total resources.

The computer's ultimate instructional contribution is to help each participant - student as well as instructor - increase his effectiveness to unprecedented levels of performance. Such a goal will be reached only through the undertaking of experimental developments carried out by dedicated, capable, and interested people over many years. But educational institutions can encourage such developments by their expressions of interest in exploiting the results of developmental efforts. Quite clearly, major "breakthroughs" are not to be just around the corner. Initial efforts should be aimed at producing practical results in a reasonable period of time. Our examination, therefore, tends to be conservative in that it emphasizes reasonably achievable goals.

Instruction in Higher Education

The man-machine partnership in the information sciences can be enormously powerful. The computer assists man in using the talents of his mind more fully. This has already been demonstrated in the physical and life sciences and in the analysis and design of large, complex systems. More recently the computer has been used in a variety of experiments as an aid in the instruction of students. This use of computers to aid human learning is called "computer assisted instruction", hereinafter referred to as CAI.

CAI exists today in four categories:

1. Problem solving;
2. Direct instruction;
3. Preparation of instructional aids; and
4. Investigations of learning processes.

   1. In problem solving the computer responds to commands from the user. For example, it is used in structural design to solve complicated problems of determining dimensions and materials required to meet specified load conditions; or in chemical engineering to determine the dynamic response of a chemical process to changes in important variables. Because of the speed with which the machine carries out computations in response to human instructions, it allows man more time to examine options and attend to the creative aspects of the problem than would otherwise be possible.

   2. In direct instruction the man-machine relationship is reversed. Using information stored by a competent teacher, the computer presents material to the student, questions him about it, then proceeds according to his responses.

   3. The computer is used in the preparation of other teaching aids, such as animated films.

   4. Finally, the computer is used as a tool for educational research in experimental investigations of learning processes. It can continuously measure and store the values of important variables and change parameters to alter significantly the nature of the experiment.

The potential usefulness of CAI is only dimly discerned, as yet. Society, confronted with continuing technological and impending social change, is demanding better educated people. At present, some sixty million students are in pre-school, elementary, secondary and higher educational institutions in this country. Each year, more students complete high school and an increasing percentage of those go on to college and enter graduate school. Yet with this rising demand for education, the supply of qualified teachers continues to be quite inadequate. CAI may prove to be of very considerable assistance in helping to meet the increasing demand for education while at the same time permitting an increase in the amount of personal attention given to the individual student. Professor Oettinger has said, "Computers will ultimately influence the evolution of human thought as profoundly as has writing."[1/] So significant an influence must become an integral element of the total instructional activity in our educational system. However, writing did not eliminate the need for teachers; neither will the use of computers.

Those familiar with what the large-scale computer has done for the very few students having frequent access to one recognize its importance. The computer must be brought to the service of many more students at all levels of education. The problems of accomplishing such an objective are economic and technological, and they are the subjects of this paper.

Present Uses of CAI

A current survey of the CAI effort, which is not exhaustive, has produced a list of 74 projects. (See Appendix 1)

As a laboratory tool, the computer has widespread use in problem solving. A number of colleges and universities are doing outstanding work. In contrast, very little has been done to permit student interaction with the computer in dealing with complex environments, though its value continues to be demonstrated by its widespread use in war and management games. A step in this direction has been taken in Westchester, New York, where elementary school pupils are given the opportunity to rule an ancient Sumerian city-state utilizing the computer for examining alternative courses of action. They learn about an economy by trying to run one. In the process they develop insight into the complexity of decision making even in a simple society. Similar opportunities abound in many other fields and should be exploited.

1/ Anthony C. Oettinger, "The Myths of Educational Technology", Saturday Review, May 18, 1968.

Although still a laboratory curiosity, the use of the computer for direct instruction has been demonstrated and is moving into prototype operation at several locations. Without minimizing differences between these projects, the common evaluation is that direct instruction by computer is reported to be effective, flexible, and well received by students and faculty, but not economically viable. Resolving this dilemma is the central problem in developing useful CAI.

In devising teacher's aids, one of the computer's most obvious capabilities is that of the generation of animated films. Technology developed at Bell Telephone Laboratories is ready for application in this area. Little has been done, and much more should be, to provide dynamic classroom demonstrations. Substantial advances could be made if adequate attention and resources were to be devoted to this problem area.

The use of the computer as an instrument for educational research has been neglected. Professor Suppes has stated that, "One of the most important gains of computer assisted instruction will be precisely (the) opportunity to collect and analyze data on an unparalleled scale...the very presence of the data will itself be a major challenge to deepen our conceptions of learning and raise our aspirations to develop more powerful scientific theories of learning."2/

Automated Quizzing -- An Immediate Opportunity

The high cost of existing direct instruction by computers results largely from the requirement for immediate feedback to the student. This conversational use of a computer depends on a time sharing or dedicated system. Both of which, at least at present, are relatively expensive. Yet conventional instruction succeeds with a turnaround time often measured in days, not seconds. Why can't the less expensive batch processor responding in a few hours contribute usefully, initially?

On existing equipment, at modest cost, students can take quizzes on readings, lectures, or laboratory work. Their answers, in machine readable form, are submitted as data to a grading program on the batch processor. The program provides each student with a detailed analysis of

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2/ Patrick Suppes, "Computer-assisted Instruction: An overview of operations and problems", IFIP Congress 68, Edinburgh, August 1968. North Holland Publishing Company, Amsterdam.

his answers and a grade, if desired; the instructor is furnished a summary which spotlights the difficulties of individuals and the class as a whole. The cost per student is negligible -- a few cents will pay for the machine produced listing. The response, though not immediate, is still far faster and more detailed than human scoring. The system, observers assert, gives students the information and incentive to learn more rapidly.

Economic grading means quizzes can be given frequently. Instructors become better informed. Fewer misunderstandings accumulate. No time is wasted on unnecessary review. Automated quizzing is not the full solution. Yet it is a contribution that can be made now at modest cost and may still be useful when immediate feedback systems are widely available.

Direct Instruction -- Cost/Benefit Analysis

Educators know how to do direct instruction through people. If computers are to be used, they must provide some advantage. Costs must be reduced or the students must learn better -- or both.

Precise data on the cost and effectiveness of computers in direct instruction are not yet available. This analysis may therefore be off by a factor of 2, but not by an order of magnitude. Yet this relatively low precision is more than adequate for immediate needs, and more detailed studies have been made, with similar results.[3/]

If an instructor is paid \$600 - \$3,600 for presenting a course of approximately 40 class hours to 20 - 30 students, student hour costs are \$.50 - \$4.50. If the price of texts and materials for each student is \$10 for 40 class hours, the additional \$.25 per student hour brings the total student hour costs to \$.75 - \$4.75.

Computer console time for presentation costs \$10 - \$20 per student hour, which is up to 40 times more than the per student cost of conventional instruction -- enough to hire a private tutor for each student.

Objective computer course preparation costs are difficult to obtain.

3/ Felix F. Kopstein, et al, Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics. U.S. Dept. of Commerce CFSTI AD 656 613, June 1967.

Dr. Silvern has estimated them at $1,000 - $10,000 per presentation hour even when the best available technology is used.[4] The student hour for preparation alone depends, of course, on the number of students who share the material. If course preparation costs are to be kept at the $.25 per student hour figure of conventional instruction, then the same material must be shared by 4,000 - 40,000 (1,000/0.25, 10,000/0.25) students!

On a multi-institutional basis, course preparation costs can be distributed over large numbers of students. Technological effort can reduce console costs. Whether this considerable administrative, financial, and technological effort is worthwhile depends upon the benefits of direct computer instruction.

How are benefits to be measured? For meaningful cost/benefit analysis, selection between systems with equal cost/benefit ratios should be a matter of indifference. Thus, benefit may be thought of as the cost of an alternative way of producing the same result. To say, for example, that a new process doubles benefits is equivalent to saying that it can give results comparable to spending twice as much on a competitive method.

The benefits the computer brings to instruction are hard to quantify. In a review of 36 reports in which use of machines was compared directly with conventional classroom instruction, Wilbur Schramm found that 18 showed no significant difference; 17, some superiority for the computer; and one, superiority for conventional teaching.[5] Though these studies suggest that the computer can provide limited benefits, quantitative generalization is obviously unwarranted. Reasonable assumptions, however, are in order: (1) student performance is unlikely to improve by more than a factor of 2, and (2) at the other extreme, the computer should not be used where it is worse than conventional instruction. Thus the denominator of the cost/benefit ratio is between 1 and 2. In other words, within the limits of precision defined, a computer performs about as well as a person but at a much higher cost.

These figures are extremely discouraging to enthusiasts of direct computer instruction. But they can also be misleading. For, as human costs are steadily increasing, computer costs have been decreasing rapidly for more than a decade, and there is every reason to believe they will continue downward.

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[4] Gloria M. Silvern, ACM Professional Development Seminar. "Computer-Assisted Instruction."

[5] Wilbur Schramm, "The Research on Programmed Instruction, an Annotated Bibliography", U.S. Office of Education Bulletin No. 35, 1964.

The hardware cost/benefit ratio has been decreasing by an order of magnitude every five years. Every indication is that this trend will continue or accelerate. E.C. Joseph estimated in 1968 that "a factor of 1,000 is achievable in ten years".6/ Confirming this view, Professor Bitzer, Director of the Computer-Based Education Research Laboratory at the University of Illinois, has proposed to the National Science Foundation the PLATO IV CAI system for the 1970's with "a cost of less than 27¢ per student hour."7/

Computer instruction costs could accordingly be competitive with conventional instruction by 1975. Thereafter, it will become increasingly more expensive to hire people instead of machines as instructors. When that happens, it will pay to use computers as fully as possible. The date 1975, however, is approximate and highly sensitive to the development effort that goes into producing efficient direct instruction systems.

Since course preparation costs are primarily people costs, they are more likely to increase than decrease, and the increase will offset machine savings. Better course preparation aids might reduce costs by a factor of 2. Even then, preparation costs will have to be spread over 2,000 - 20,000 students just to break even. That requirement is too high for most single institutions and preparation costs must, therefore, be shared among several.

The important resulting judgements that can be made, then, are:

1. Competitive direct instruction by computers is 5 to 10 years away;

2. Investing in the development of economical systems can bring substantial return through inventive realizations of the computer's potential in instruction; and

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6/ E. C. Joseph, "Computers: Trends toward the future", IFIP Congress 68, Edinburgh, August 1968. North-Holland Publishing Company, Amsterdam.

7/ Donald L. Bitzer, A Large-Scale Computer-Based Education System With Demonstration Centers, Computer-Based Education Research Laboratory, University of Illinois, Urbana, Illinois, November 13, 1967.

3. Computer course preparation costs must be shared on a multi-institutional basis for the indefinite future.

Requirements for Economical Direct Instruction

Efficient immediate feedback direct instruction systems need (1) more use of problem segmentation to exploit the advantages of *specialization* and module sharing, (2) the introduction of *sensible standards* to promote cost sharing, (3) *system optimization* for operational use, and (4) more *effective machine assistance in course preparation*.

1. As in any new field, early experiments have been carried out on largely an *ad hoc* basis necessarily resulting in duplication of effort. Too many concepts are being reinvented, often with trivial variations which serve only to inhibit standardization. System components are usually developed in a form which makes them useless to any similar project. Little or no advantage is taken of the substantial *benefits of specialization*. As preliminary learning goes on, such inefficiencies are unavoidable, but they must be eliminated as quickly as practicable.

   Some progress has been made in the separation of software support for course preparation. Coursewriter 1 and 2, Lyric, and Planit are notable steps in this direction.[8,9,10] Similar accomplishments in the planning, creation, validation, maintenance, and review of programmed courses will encourage modularity and economy.

8/ COURSEWRITER. *Computer-Assisted Instruction*, IBM Research Reports, Vol. 2, No. 1, January 1966, Thomas J. Watson Research Center, Yorktown Heights, New York.

9/ LYRIC. G. M. Silvern, L. C. Silvern, "Computer-assisted instruction: specification of attributes for CAI programs and programmers", *Proceedings of 21st National ACM Conference*, 1966.

10/ PLANIT. Samuel L. Feingold, "PLANIT-A Flexible language designed for computer-human interaction", *Fall Joint Computer Conference*. 1967. American Federation of Information Processing Societies.

The greatest saving will come in the separation of systems for course development from those used in operational presentation. The optimum system for presentation is poorly suited for course development. It is both uneconomic and unnecessary to include a significant course development capability in an optimized, operational presentation system. The more elaborate, less used, and costly preparation capability requires a more versatile man-machine system.

2. The need for sensible standards is based on the fact that direct instruction is economical only if the same course can be used on several campuses. There must be (a) agreement on general course content and approach, (b) effective means for sharing preparation costs, and (c) products that can be used without change. Requirements (a) and (b) are primarily nontechnological; they are difficult but can be met. Requirement (c) involves easy transfer of programs and data to various environments. This invites a technological decision between two apparent options:

   Identical hardware at all sites; or
   Carefully designed, implemented, and maintained machine independent software.

   Hardware standardization will lock the educational community into a particular system. That arrangement, even if possible today, is not feasible for the future. New computer hardware with substantial cost/benefit advantages makes any system obsolete in a few years. Thus, in the long run, transferability of courses cannot be provided through hardware.

   Experience with high-level programming languages shows that a useful level of machine independence is attainable through software. To obtain the advantages, responsibility must be centralized in a design group which, recognizing the importance of standards, arrives at an eclectic software design suitable for many machines. A ten year lifetime on a wide variety of computers seems a reasonable expectation. Implementation, validation, and maintenance by the centralized group then can insure machine independence. Improvements will continue to be possible so long as they are machine independent and "upward compatible".

3. System optimization for direct computer instruction presently has serious shortcomings. Presentation is being done today on systems optimized for other purposes. Often the only merit of the input-output equipment is its ready availability.

Presentation consoles should be inexpensive ($100 - $1,000), rugged, reliable, easy to repair, quiet, modular, designed for mass production, simple to use, and capable of high output and low input speeds. The console needed is closer in concept to Bell's Picture Phone than to the Model 33 Teletype (or equivalent) generally used. The processor should be closer to a store and forward message switching center than to a general purpose, time sharing computer. A negligible amount of computing, but very large storage capacity, is essential, and the system, when it fails, must "fail softly".

Better knowledge of the design requirements for both a minimum cost and an optimal cost/benefit console is needed. If the educational community can agree on standard requirements, manufacturers would undoubtedly develop competitive devices at their own expense.

Communication between consoles and the central computer is also an important area of design. Most time sharing computer systems have been developed on the assumption that remote use requires telephone lines; their use becomes a constraint. Presentation systems, however, should exploit the fact that colleges and universities will continue to be centralized. Centralization can save substantial amounts through shared storage and the use of alternative transmission facilities. Even a video channel is economical when it can be provided by a short coaxial cable. To be sure, compatibility with Data Phone will continue to be desirable for special uses, but telephone system limitations should not be allowed to dominate the design.

4. For course preparation a computing system must be versatile. It should be an overset of the presentation system so the course author can see how any aspect will appear to a student. It must also provide substantial software support to course preparation and let instructors examine aspects not visible to students.

   The basic component is a powerful, standard, machine dependent course writing language. Incremental course construction and automatic assistance in the complex process of keeping track of course structure should be central features of the system. Widespread default options, the implications of which are displayed to the course author, can help him use his time more effectively. Special software should be available to aid in course validation with instrumentation to help pinpoint problem areas.

   Overall, the ideal system for course preparation resembles a general purpose, time sharing system augmented by problem oriented software. Since the cost of producing and maintaining this kind of system will be high and its use by any single institution relatively low, it is an obvious candidate for centralization.

Preparing for Direct Instruction

The finest direct instruction system is worthless until used. Once constructed, what shall be done with it? How shall it be put to effective use? What preparations should be made for its arrival? The answers to these questions lie in the needs of the educational community and the realities of system structure achievable in the next few years. Now is the time to examine these realities.

Direct instruction will be most effective when it is applied to (1) large student populations in (2) courses with clearly defined goals and teaching methods where (3) no extensive research is needed before the computer can be used. The evident choices are freshman courses in the various sciences, foreign languages, mathematics, and economics. All are about equally attractive, and the first choice should depend upon the greatest need.

A distinguished advisory committee representing a broad cross section of the educational community should decide on priorities and recommend course authors. They decide what is to be included and how the materials should be presented. With the approval of the advisory committee and the assistance of a permanent staff of specialists, the authors prepare and validate the courses. Distribution to campuses, maintenance of material and system, and assistance in operations are best provided by a permanent cadre. In that arrangement, continuing needs are filled by permanent staff, and intermittent efforts come from people primarily interested in their own specialities.

The key weakness of this approach is its necessary reliance on time consuming cooperative action. The establishment of the advisory committee should, therefore, begin as quickly as possible.

Needs in Other Areas of CAI

Too little has been done to permit a meaningful cost/benefit analysis of the computer as a laboratory tool, teaching aid, and instrument for educational research. To determine what is possible, there is no substitute for actual reduction to practice. It refines goals, confronts real problems, demonstrates potential, and produces data for evaluation. The computer techniques of war gaming, film production, and on-line experimental control are available and may have useful applications to educational problems. As such techniques prove their worth, the new technology must be transferred rapidly to the educational community for practical use.

Breakthroughs in Direct Instruction

To this point the analysis has been conservative. Yet the machine's greatest potential is unquestionably the substantial improvement of instruction to enhance student learning. At the present level of understanding of teaching learning processes, there is little merit in actively seeking technological breakthroughs in instruction. The objective is the best education each individual can use at an acceptable cost. Right now, direct instruction within reasonable economic constraints appears to be the best and swiftest approach, but the objective, not the approach, is the important consideration. Chance favors the prepared mind watching for a better way.

A Proposed Program

To help bring the information and computing sciences to the service of education, a large-scale, long-range program is required. Such a program is outlined in Appendix 3 of this Chapter. Its goal is to respond to known needs of the entire educational community and it stresses what is done best centrally and cooperatively. The advantages of sharing development costs of computer assisted instruction invite a major effort in that area.

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APPENDIX 1

Seventy-four CAI Projects

1968

Institution: Altoona Area School District
Principal Investigator: Thomas Long
Project: Counselor training in statistical analysis
Use of Computer: Direct instruction
Educational Level: Professional

Institution: American Institute for Research in Behavioral Sciences
Principal Investigator: William W. Cooley
Project: Educational research
Use of Computer:
Educational Level:

Institution: Association for Educational Data Systems
Principal Investigator: John W. Sullivan
Project: Advanced data processing training curriculum
Use of Computer: Direct instruction
Educational Level: Professional

Institution: Battelle Memorial Institute
Principal Investigator: Slowter
Project: Evaluating the efficiency and effect of self instructional methods for selected areas of vocational education
Use of Computer: Direct instruction
Educational Level: Vocational

Institution: Bentley College of Accounting and Finance
Principal Investigator: Edward Y. George
Project: Mathematics curriculum for under graduate business students
Use of Computer: Direct instruction
Educational Level: College/University

Institution: Bolt, Beranek & Newman
Principal Investigators: Feurzieg and Bobrow
Project: Computer language that permits tutorial interaction between student and computer
Use of Computer: Direct instruction
Educational Level:

Institution: Bolt, Beranek & Newman
Principal Investigator: Dr. John A. Swets
Project: Psycho-physical laboratory teaching systems for diagnosing medical ailments; Decision making in business and management; Military strategy; Investigation of scientific problems; Conversational teaching machine; Languages for problem solving
Use of Computer: Laboratory tool
Educational Level:

Institution: Bucknell University
Principal Investigator: J. William Moore
Project: Internship and research program as part of graduate program in educational research
Use of Computer:
Educational Level:

Institution: University of California
Principal Investigator: Wood
Project: Electronic Computer training and research facility
Use of Computer: Direct instruction
Educational Level: Professional

Institution: University of California, Berkeley
Principal Investigator: Starkweather
Project: Computer science instruction in elementary schools
Use of Computer: Direct instruction
Educational Level: Elementary

Institution: University of California, Berkeley
Principal Investigator: Dr. John Starkweather
Project: Development of Computest, can be used for simulation and study of interview and counseling procedures and gathering information; project to explore role of student-constructed materials in the learning and attitudes of fourth to eighth graders
Use of Computer: Laboratory tool
Educational Level:

Institution:	University of California, Irvine
Principal Investigator:	Dr. Fred Tonge
Project:	Development of mathematics and statistics curriculum; Design and implementation of inquiry system; Symbol manipulation capability
Use of Computer:	Direct instruction; Laboratory tool
Educational Level:	College/University

Institution:	University of California, Santa Barbara
Principal Investigator:	Dr. Glenn Culler, Computing Center
Project:	Problem solving in mathematics and related subjects; Experimental communications programs in psychology, biometrics, physical sciences and mathematics
Use of Computer:	Laboratory tool
Educational Level:	College/University

Institution:	Decision Sciences Laboratory
Principal Investigator:	Dr. Sylvia R. Mayer
Project:	CAI for users of an Air Force Computer system; Training takes place within the same system for which the user is being trained
Use of Computer:	Direct instruction
Educational Level:	Military

Institution:	University of Denver
Principal Investigator:	Entenberg
Project:	Computer technology in collegiate business education
Use of Computer:	Direct instruction
Educational Level:	College/University

Institution:	Department of Defense, United States Army
Principal Investigator:	Seidel
Project:	Computer assisted training
Use of Computer:	Direct instruction
Educational Level:	Military

Institution:	Central Michigan Education Resource Council
Principal Investigator:	Morford
Project:	Interconnecting school districts in large geographic areas of low population density by electronic means for the provision of instructional and administrative services
Use of Computer:	
Educational Level:	Elementary; High school

Institution: Educational Testing Service
Principal Investigator: Dr. Carl Helm
Project: Use of machines in (1) developing verbal interpretations of test scores, (2) creating and assembling test materials, (3) test administration methods that will provide rapid feedback of test results, (4) monitoring of learning in CAI, (5) problems of sequence in instruction
Use of Computer: Laboratory tool
Educational Level:

Institution: Florida State University
Principal Investigator: Burkman
Project: Development and evaluation of a science curriculum for grades 7, 8 and 9
Use of Computer: Direct instruction
Educational Level: Elementary, Secondary

Institution: Florida State University
Principal Investigator: Dr. Duncan Hansen
Project: Research in CAI for trigonometry, geometry and educational measurement
Use of Computer: Direct instruction
Educational Level: Secondary

Institution: Florida State University
Principal Investigator: Hansen
Project: Research and implementation of collegiate instruction of physics via CAI
Use of Computer: Direct instruction
Educational Level: College/University

Institution: Florida State University
Principal Investigator: Smith
Project: Prevocational education literacy courses
Use of Computer: Direct instruction
Educational Level: Vocational

Institution:
Principal Investigator: Catherine J. Garvey
Project: Developmental testing of a self-instructional French course
Use of Computer: Direct instruction
Educational Level:

Institution: University of Georgia
Principal Investigator: Greene
Project: Improving research skills in major school subjects
Use of Computer: Laboratory tool
Educational Level:

Institution: Hamline University
Principal Investigator: Downing
Project: Evaluation and revision of open laboratory procedures at the college freshman level
Use of Computer: Laboratory tool
Educational Level: College/University

Institution: University of Hartford
Principal Investigator: Douglas M. Fellows
Project: Curriculum for electro-mechanical technicians
Use of Computer: Direct instruction
Educational Level: Technical

Institution: Harvard University
Principal Investigator: Miller
Project: Computer instrumented studies of cognitive processes
Use of Computer: Laboratory tool
Educational Level:

Institution: University of Illinois
Principal Investigator: Dr. Donald Bitzer
Project: PLATO (Programmed Logic for Automatic Teaching Operation)
Use of Computer: Direct instruction
Educational Level: College/University

Institution: University of Illinois
Principal Investigator: Easley
Project: Computerized system for instructional response and analysis
Use of Computer: Direct instruction
Educational Level:

Institution: University of Illinois
Principal Investigator: Hartley
Project: Design and testing of a form for student evaluation of teaching
Use of Computer: Direct instruction
Educational Level:

Institution:	University of Illinois
Principal Investigator:	Dr. L. M. Stolurow
Project:	SOCRATES-research on instruction to make the computer act more like a sensitive human tutor and less a preprogrammed machine; evaluates needs of student
Use of Computer:	Direct instruction
Educational Level:	

Institution:	IBM Instructional Systems Development Dept.
Principal Investigator:	Dr. E. N. Adams, Director
Project:	Curriculum projects in statistics, stenotype, German, computer languages, second language learning, reading skills
Use of Computer:	Direct instruction
Educational Level:	All levels

Institution	IBM Advanced Systems Development Division
Principal Investigator:	Dr. Richard S. Hirsch
Project:	Simulated chemistry and physics laboratories
Use of Computer:	Laboratory tool
Educational Level:	College/University

Institution:	IBM Field Engineering Division
Principal Investigator:	Mr. Harvey S. Long
Project:	Teaching terminals for training for System 360 and fundamentals of data processing
Use of Computer:	Direct instruction
Educational Level:	Business

Institution:	Johns Hopkins University
Principal Investigator:	
Project:	Research on simulation as method of instruction
Use of Computer:	Laboratory tool
Educational Level:	

Institution:	Massachusetts Board of Education
Principal Investigator:	Dr. Jesse D. Richardson
Project:	Mathematics
Use of Computer:	Direct instruction
Educational Level:	Grades 6, 9 and 11

Institution: University of Michigan
Principal Investigator: Dr. John Fowler, Commission on College Physics
Project: Materials for instruction in optics, acceleration and electrostatics, other support material for physics instruction
Use of Computer: Direct instruction
Educational Level: College/University

Institution: University of Michigan
Principal Investigator: Dr. Harlan Lane
Project: Speech auto-instructional devise for research on training in the prosodic characteristics of speech; speech analysis
Use of Computer: Laboratory tool
Educational Level:

Institution: University of Michigan
Principal Investigator: Dr. William R. Uttal
Project: Research on physiological correlates of learning mathematics
Use of Computer: Laboratory tool
Educational Level:

Institution: University of Michigan
Principal Investigator: Vinsonhaler
Project: Improving accessibility of educational materials retrieval of educational and psychological tests
Use of Computer: Laboratory tool
Educational Level:

Institution: University of Michigan
Principal Investigator: Dr. Karl L. Zinn
Project: Computer technology in education; course development, author aids, retrieval and display information, student response processing and "on line" interaction between author and student; author input language
Use of Computer: Laboratory tool
Educational Level: College/University

Institution: Michigan State University
Principal Investigator: Dr. Robert Davis
Project: Student attitudes toward CAI automated testing
Use of Computer: Direct instruction; Laboratory tool
Educational Level: College/University

Institution: Michigan State University
Principal Investigator: Charles Frye
Project: Plan for students to operate computer on a real time basis using it both as a teaching machine and calculator; will train students in statistics and computer procedures
Use of Computer: Laboratory tool; Direct instruction
Educational Level: College/University

Institution: Michigan State University
Principal Investigator: Marzollo
Project: Methods of presenting programmed instruction materials by teaching machines and computers
Use of Computer: Direct instruction
Educational Level:

Institution: University of Nevada
Principal Investigator: Cotter
Project: Intercollegiate competition in computer simulation of business grants
Use of Computer: Laboratory tool
Educational Level: College/University

Institution: University of Oklahoma
Principal Investigator: Mr. William C. Harless
Project: Medical curriculum
Use of Computer: Direct instruction
Educational Level: Medical schools

Institution: Oklahoma State Board of Vocational Education
Principal Investigator: Francis Tuttle
Project: Institute to train data processing teachers
Use of Computer: Direct instruction
Educational Level: Professional

Institution: Pennsylvania State University
Principal Investigator: Neal C. Deihl
Project: Instrumental music
Use of Computer: Direct instruction
Educational Level:

Institution: Pennsylvania State University
Principal Investigator: Dr. Harold E. Mitzel
Project: Development and presentation of college courses in management accounting, engineering, economics, modern mathematics and audiology by computer teleprocessing; assessment of experimental teaching strategies in CAI courses for tech. edu. programs.
Use of Computer: Direct Instruction
Educational Level: College/University

Institution: University of Pittsburgh
Principal Investigator: Bolvin
Project: Individually prescribed instruction
Use of Computer: Direct instruction
Educational Level:

Institution: University of Pittsburgh
Principal Investigator: Dr. Robert Glaser
Project: Learn laboratory; progress recording, assignment scheduling, learning strategies, author language
Use of Computer: Laboratory tool
Educational Level: Elementary

Institution: University of Pittsburgh
Principal Investigator: Harding
Project: Markov chain model of pupil progress
Use of Computer: Direct instruction
Educational Level:

Institution: University of Pittsburgh
Principal Investigator: Dr. Omar K. Moore
Project: Edison Responsive Environment Instrument-computerized typewriter capable of reproducing several of the response actions of a human teacher
Use of Computer: Direct instruction
Educational Level: Elementary

Institution: University of Pittsburgh
Principal Investigator: Ramage
Project: Computer based instructional laboratory
Use of Computer: Direct instruction
Educational Level:

Institution: Providence College
Principal Investigator: George McGregor
Project: Instruction for vocational teachers
Use of Computer: Direct instruction
Educational Level: Professional

Institution: Rensselaer Polytechnic Institute
Principal Investigator: Roy
Project: CAI course in Boolean algebra and logic design
Use of Computer: Direct instruction
Educational Level: College/University

Institution: University of Rochester
Principal Investigator: William H. Clark
Project: Programmed foreign language courses in secondary school with specially trained teachers
Use of Computer: Direct instruction
Educational Level: Secondary

Institution: E. F. Shelley & Co., Inc.
Principal Investigator: Edwin F. Shelley
Project: Comprehensive secondary school curriculum
Use of Computer Direct instruction
Educational Level: Secondary

Institution: University of Southern California
Principal Investigator: Abrahamson
Project: Medical training simulations for anesthesiologists
Use of Computer: Laboratory tool
Educational Level: Medical

Institution: Stanford University
Principal Investigator: Scott
Project: Investigations on using transformations in high school geometry
Use of Computer: Direct instruction
Educational Level: Secondary

Institution: Stanford University
Principal Investigator: Patrick Suppes
Project: Analysis of second-language learning with emphasis on Russian
Use of Computer: Laboratory tool
Educational Level:

Institution: Stanford University
Principal Investigator: Dr. Patrick Suppes
Project: Primary reading and arithmetic curriculum; research in learning
Use of Computer: Direct instruction
Educational Level: Elementary

Institution: Stanford University
Principal Investigator: Dr. Patrick Suppes
Project: Development of math concepts in children
Use of Computer: Computer based laboratory for direct instruction
Educational Level: Elementary

Institution: Stanford University
Principal Investigator: Joseph A. Van Campen
Project: Supplemental materials for computer-based first-year course in Russian
Use of Computer: Direct instruction
Educational Level: College/University

Institution: Stanford Electronics Laboratories
Principal Investigator: Richard Smallwood
Project: Teaching system adjusted to student's instructional history
Use of Computer: Direct instruction
Educational Level:

Institution: Systems Development Corporation
Principal Investigator: John Cogswell
Project: Vocational counseling
Use of Computer: Direct instruction
Educational Level: Vocational

Institution: Systems Development Corporation
Principal Investigator: Dr. Harry Silberman
Project: CLASS-Computer based laboratory for automation of school systems; student counseling
Use of Computer: Direct instruction
Educational Level: Elementary; Secondary

Institution: Systems Development Corporation
Principal Investigator: Standhammer
Project: Computer assisted teaching of mathematics
Use of Computer: Direct instruction
Educational Level:

Institution: Systems Operation Support
Principal Investigator: Gilbert B. Rozran
Project: Electronics and auto mechanics
Use of Computer: Direct instruction
Educational Level: Technical

Institution: University of Texas
Principal Investigator: Dr. C. Victor Bunderson
Project: Research in learning and instruction curriculum projects; simulated freshman chemistry lab, elementary statistics, scientific German, heuristic problem solving
Use of Computer: Laboratory tool; Direct instruction
Educational Level:

Institution: University of Texas
Principal Investigator: Wolfe
Project: Special education instructional materials center
Use of Computer: Direct instruction
Educational Level:

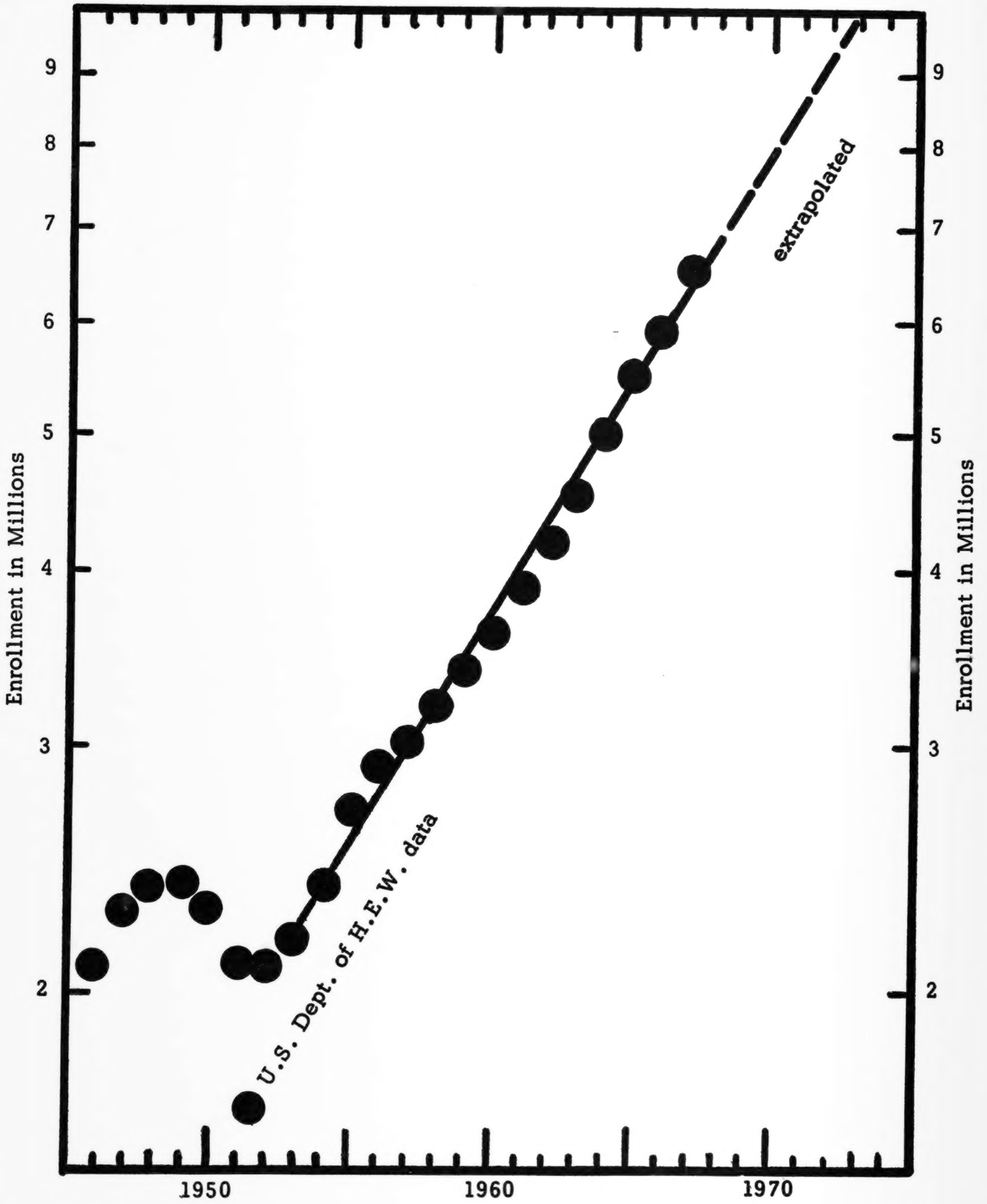
Institution: Virginia University
Principal Investigator: Mary A. MacDougall
Project: Programmed science materials for fourth graders
Use of Computer: Direct instruction
Educational Level: Elementary

Institution: Wayne State University
Principal Investigator: Smith
Project: Probability estimates of the capacities of intermediate pupils to understand selected physical science concepts
Use of Computer: Laboratory tool
Educational Level: Elementary, Secondary

Institution: Northern Westchester Board of Cooperative Educational Services
Principal Investigator: Dr. Richard L. Wing
Project: Simulated economics game
Use of Computer: Laboratory tool
Educational Level: Elementary

APPENDIX 2

The Growth of Enrollment
in U.S. Colleges & Universities



APPENDIX 3

A PLAN

Introduction

This appendix describes a plan of action which, if implemented, could result in cost-effective computer assisted instruction in approximately five years; it is coupled with selected exploratory research of longer range value. In each of the six tasks that are recommended, a moderately detailed schedule with manpower requirement is provided. The intent is to choose a desirable rate of progress, while allowing adequate time for essential coordination with the higher education community. A significant reduction in time could be purchased only with a substantial increase in funding. On the other hand, even a moderate budget reduction would result in a much longer time before practical utilization of results is feasible.

No schedule or manpower has been suggested for distributing the new technology into the nation's colleges and universities. The more forward looking institutions, of course, will pick up and apply advances with minimal assistance. It is highly probable, however, that the very campuses which have the greatest need for cost-effective CAI will be among the last to adopt it. Unfortunately, no clever or efficient schemes for diffusing the new technology are apparent. Something resembling the "county agent" of the Department of Agriculture will probably be the most effective technique; estimates of the number of "agents" needed range as high as 600. Clearly, expenditures of this magnitude must await operational proof of CAI cost effectiveness. This plan is directed toward providing either that proof or a solid refutation.

Cost-Effective Direct Instruction

Demonstration of cost-effective direct instruction depends upon three key developments:

1. an effective presentation system;

2. advanced course preparation software; and

3. demonstration courses.

To insure the best attainable result, it is recommended that these three aspects proceed concurrently and that very close interaction be maintained among the developers at all times.

The primary objective is to produce a fully tested, operational system which will be available for replication in quantity as soon as the project is completed. Full use of the special capabilities of private industry is anticipated for the production of many components; such units must be designed specifically for CAI use and procured competitively, with complete disclosure required so production models can be obtained form a variety of sources.

Considerable care must be exercised to promote the widest possible dissemination of plans to potential users for constructive criticism. Since the systems proposed are expected to have a useful lifetime of at least ten years (and an influence long afterward), it is crucial that the design be influenced by those who can make positive contributions.

DIRECT INSTRUCTION PRESENTATION SYSTEM
(The Hardware)

An Economically Feasible Presentation System

A feasible computer based direct instruction presentation system must have a cost/benefit ratio less than conventional teaching methods. It is anticipated that at least initially this requirement can best be met in high enrollment, lower division courses.

The key to cost-effective CAI is a presentation system of reasonable flexibility which can operate for less than 50¢ per student hour. Although no specific design is recommended here, it is evident that several practicable alternatives are available. The selection among these choices should be made by the organization which will construct the prototype -- after detailed consultation with the higher educational community. Subsequently, the necessary hardware will be procured competitively from industry; software (including training materials) will be developed by the designers. A full year of exploratory operation and refinement is scheduled before release of the design for replication.

DIRECT INSTRUCTION PRESENTATION SYSTEM

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	2	
Survey available technology	6	2	
Perform cost/benefit analysis	9	2	
Design a minimum cost/benefit presentation system	12	2	8
SECOND YEAR			
Prepare detailed specifications	15	4	
Circulate specifications to community for comment	18	0	
Establish criteria for selection	18	2	
Revise specifications	21	2	
Solicit competitive bids for an experimental system	24	0	8
THIRD YEAR			
Evaluate proposals	27	2	
Order experimental system	27	0	
Prepare training materials for system	36	4	
Train experimental users	36	4	
Install experimental system at the Institute	36	2	12
FOURTH YEAR			
Limited operation for evaluation	42	6	
Begin training community	42	4	
Design and implement necessary changes	45	2	
Revise and publish detailed specifications and training materials	48	2	
Begin advisory services for community	48	4	18
FIFTH AND SUBSEQUENT YEARS			
Begin full scale operation at the Institute			
Operations management		2	
Coordinate community installations		4	
System maintenance and improvement		4	
Advisory and training services		6	16

MACHINE INDEPENDENT COURSE PREPARATION SOFTWARE

The most effective use of skilled manpower for the production of courses requires course preparation software of advanced design which embodies the greatest practicable degree of machine independence. Carefully designed and well implemented software could cut the cost of course preparation and revision in half; full use of the possibilities of machine independence could double the useful life of courses. Both of these are essential to hold preparation costs to a minimum and thus permit wider applicability of CAI.

The plan is intended to benefit from the already significant research that has been done in course author languages. The first year is devoted to bringing to bear the results of present experimentation on the design of an eclectic system. After careful review by the educational community and incorporation of their recommendations, the software and training materials will be prepared by the designers. All software should be constructed in a highly modular fashion with considerable emphasis on ease of movement to subsequent machines. A full year of test, evaluation and refinement is scheduled before the system is released for general use.

MACHINE INDEPENDENT COURSE PREPARATION SOFTWARE

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Survey existing systems	3	2	
Design an eclectic course preparation system	6	4	
Evaluate and select a machine independent language for use in implementation	7	2	
Prepare detailed specifications	12	4	12
SECOND YEAR			
Circulate specifications to community for comment	18	0	
Select a computer for initial implementation	18	2	
Revise specifications	24	2	
Prepare software modules	24	8	12
THIRD YEAR			
Implement experimental course preparation system	36	10	
Prepare training materials and course preparation implementation guide	36	4	
Train experimental users	36	2	16
FOURTH YEAR			
Experimental operation and evaluation	42	6	
Begin training community	42	4	
Design and make changes to the system	45	2	
Revise and publish specifications, implementation guide and training materials	48	2	
Begin advisory services	48	2	16
FIFTH AND SUBSEQUENT YEARS			
Begin full scale operation at the Institute			
Operations management		2	
System maintenance and improvement		8	
Advisory and training services		4	14

PREPARATION OF DEMONSTRATION CAI COURSES

Concurrent development of a series of demonstration courses is recommended to:

1. insure close contact of the system and software developers with the reality of practical problems, and

2. provide meaningful courses that are ready for use as soon as the system becomes generally available.

The relatively small staff devoted to preparation of demonstration courses will be guided and assisted by a large group of distinguished consultants. Each course will require approximately four years for development. The first year will be devoted to the preparation and testing of detailed specifications. The second year will be devoted to implementation. The third year is reserved for test, evaluation and improvements, plus the preparation of necessary manuals. In the last year, actual use by a large body of students will lead to final changes and general release.

In the early years, initiation of one new course per year is anticipated. The selection of priority and qualified authors will rest in an advisory committee drawn from the educational community. The advisory committee should also pay careful attention to the vexing but extremely important problem of compensating course authors.

Recognizing the frequent need for revision in our rapidly changing world, full use should be made of the computer to promote quick and frequent changes in course content whenever the need arises.

PREPARATION OF DEMONSTRATION CAI COURSES

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Prepare detailed specification for first (test) course	12	3	
Train initial staff in use of course preparation software	12	1	4
SECOND YEAR			
Prepare detailed specification for second course	24	3	
Train second staff in use of course preparation software	24	1	
Implement first (test) course	24	4	8
THIRD YEAR			
Experimental use and evaluation of first (test) course	30	2	
Implement necessary changes in first (test) course	36	1	
Prepare teacher's manual for first (test) course	36	1	
Implement second course	36	4	
Prepare detailed specification for third course	36	3	
Train third course staff in use of course preparation software	36	1	12
FOURTH YEAR			
Trial use of first course by students	42	0	
Implement necessary changes in first course and manual	45	1	
"Publish" (for general use) initial version of first course and manual	48	1	
Experimental use and evaluation of second course	42	2	
Implement necessary changes in second course	48	1	
Prepare teacher's manual for second course	48	1	
Implement third course	48	4	

PREPARATION OF DEMONSTRATION CAI COURSES

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FOURTH YEAR continued			
Prepare detailed specification for fourth course	48	3	
Train fourth course staff in use of course preparation software	48	1	
Initiate advisory service	48	2	16

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Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
Nth YEAR ($N \geq 5$)			
Evaluate initial operational experience on (N-4)th course	12(N-1)+6	1	
Revise (N-4)th course and manual	12N	1	
"Publish" operational version of (N-4)th course	12N	1	
Initiate maintenance of (N-4)th course	12N	1	
Trial use of (N-3)rd course by students	12(N-1)+6	0	
Implement necessary changes in (N-3)rd course and manual	12(N-1)+9	1	
"Publish" initial version of (N-3)rd course and manual	12N	1	
Experimental use and evaluation of (N-2)nd course	12(N-1)+6	2	
Implement necessary changes in (N-2)nd course	12N	1	
Prepare teacher's manual for (N-2)nd course	12N	1	
Implement (N-1)st course	12N	4	
Prepare detailed specification for Nth course	12N	3	
Train staff of Nth course in use of course preparation software	12N	1	
Advisory service		2	20

INSTRUCTOR'S AIDS

Exploratory research and development is needed to advance the use of computers to assist in group instruction. An immediate opportunity is exploitation of the already developed techniques for producing computer animated instructional films. In the future, instructors should have the opportunity to use the computer as a part of the lecture room environment; to do this effectively, more active innovation is necessary.

A relatively small group is postulated which will begin by making facilities for computer animated films available easily and economically to a large sector of higher education. Then, with the guidance of a committee which is representative of the community, a series of developments would be designed, implemented, tested and made available.

INSTRUCTOR'S AIDS

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Survey existing aids	6	2	
Select most useful aids	9	1	
Document selected aids	12	3	6
SECOND YEAR			
Circulate documentation to community for comment	15	0	
Select two aids of widest applicability	18	1	
Prepare detailed specifications for first selected aid	24	3	
Prepare detailed specifications for a computer animated film system	18	3	
Solicit competitive bids for computer animated film hardware	18	0	
Establish criteria for evaluation of hardware proposals	21	1	
Evaluate hardware proposals	24	1	
Order hardware for film system	24	0	9
THIRD YEAR			
Implement computer animated film system	36	5	
Document film system	36	2	
Train community in use of film system	36	1	
Circulate detailed specifications of first selected system to community	27	0	
Make necessary changes in specifications	30	1	
Solicit competitive bids for needed hardware	30	0	
Establish criteria for evaluation of proposals	33	1	
Evaluate hardware proposals	36	1	
Order hardware	36	0	
Prepare detailed specifications for second selected system	36	3	
Solicit community interest for third system	36	0	14

INSTRUCTOR'S AIDS
continued

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
Nth YEAR (N ≥ 4)			
Implement (N-3)rd system	12N	5	
Document (N-3)rd system	12N	2	
Train community in use of (N-3)rd system	12N	1	
Circulate specifications of (N-2)nd system to community	12(N-1)+3	0	
Make necessary changes in specifications of (N-2)nd system	12(N-1)+6	1	
Solicit competitive bids for hardware for (N-2)nd system	12(N-1)+6	0	
Establish criteria for evaluation of proposals for (N-2) nd system	12(N-1)+9	1	
Evaluate hardware proposals for (N-2)nd system	12N	1	
Order hardware for (N-2)nd system	12N	0	
Prepare detailed specifications for (N-1)st selected system	12N	3	
Solicit community interest for Nth system	12N	0	14

LABORATORY TOOLS

In a narrow sense, use of the computer as a laboratory tool to help teach, for example, computer programming or civil engineering, is the most developed instructional application. In the broader sense of providing abstract environments for learning, however, the potential has been barely tapped. New developments -- such as economic simulators which give students practical experience in directing a company or college -- could have far reaching effects by building understanding of the complexity of actual decision making.

A small effort to develop prototype systems for use and to serve as inspiration for extensions by other groups seems most appropriate. Early emphasis is placed on economic simulation. But, at the same time, the educational community should be consulted for advice on the needs and possibilities for additional developments.

LABORATORY TOOLS

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Survey existing tools	6	2	
Select most useful tools	9	1	
Document selected tools	12	3	6
SECOND YEAR			
Circulate documentation to community for comment	15	0	
Select two tools of widest applicability	18	1	
Prepare detailed specifications for first selected tool	24	3	
Prepare detailed specifications for an economic simulator	18	3	
Solicit competitive bids for economic simulator hardware	18	0	
Establish criteria for evaluation of hardware proposals	21	1	
Evaluate hardware proposals	24	1	
Order hardware for economic simulator	24	0	9
THIRD YEAR			
Implement economic simulator	36	5	
Document economic simulator	36	2	
Train community in use of economic simulator	36	1	
Circulate detailed specifications of first selected system to community	27	0	
Make necessary changes in specifications	30	1	
Solicit competitive bids for needed hardware	30	0	
Establish criteria for evaluation of proposals	33	1	
Evaluate hardware proposals	36	1	
Order hardware	36	0	
Prepare detailed specifications for second selected system	36	3	
Solicit community interest for third system	36	0	14

LABORATORY TOOLS

continued...

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
Nth YEAR (N ≥ 4)			
Implement (N-3)rd system	12N	5	
Document (N-3)rd system	12N	2	
Train community in use of (N-3)rd system	12N	1	
Circulate specifications of (N-2)nd system to community	12(N-1)+3	0	
Make necessary changes in specifications of (N-2)nd system	12(N-1)+6	1	
Solicit competitive bids for hardware for (N-2)nd system	12(N-1)+6	0	
Establish criteria for evaluation of proposals for (N-2)nd system	12(N-1)+9	1	
Evaluate hardware proposals for (N-2)nd system	12N	1	
Order hardware for (N-2)nd system	12N	0	
Prepare detailed specifications for (N-1)st selected system	12N	3	
Solicit community interest for Nth system	12N	0	14

EMPIRICAL STUDY OF LEARNING

Development of the proposed cost-effective CAI presentation system will provide an important opportunity for advanced research into the nature of the learning process. Detailed empirical studies of the student progress through actual course material may -- in the long run -- lead to more effective methods of teaching and provide graduates that are substantially superior in depth and breadth of understanding.

The objective of the small group recommended for this effort is exploitation of the unique resource of the developing presentation system to learn about the nature of learning. It should design experiments and procure the necessary instrumentation during the construction of the CAI system. As soon as the system is operational, the group should begin to measure parameters thought relevant and construct formal models of learning behavior. These models can be used immediately in the refinement of the CAI prototype system.

The study of learning can be expected to extend over a long period. This study should be continued in close association with the developers of enhanced CAI systems for the mutual benefit of both areas of study. Perhaps, in a decade, fundamentally different methods of instruction can evolve which will lead to vastly improved student performance and help prepare them to cope with our increasingly complex society.

EMPIRICAL STUDY OF LEARNING

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish detailed objectives	12	1	
Design experiment	12	3	4
SECOND YEAR			
Prepare detailed specifications for instrumentation	18	2	
Solicit competitive bids for instrumentation hardware	18	0	
Establish criteria for evaluation of proposals	21	1	
Evaluate hardware proposals	24	1	
Order instrumentation hardware	24	0	
Begin construction of software interface	24	2	6
THIRD YEAR			
Continue construction of software interface	30	2	
Install instrumentation hardware	30	2	
Assemble complete instrumentation system	33	2	
Train system users	33	1	
Limited operation of system for evaluation	36	1	8
FOURTH YEAR			
Design and implement necessary changes	39	2	
Integrate instrumentation with first direct instruction course	45	4	
Trial use of combined instruction-instrumentation system	48	2	8
FIFTH YEAR			
Design and implement necessary changes to combined system	51	2	
Collect data on student performance	60	2	
Design data reduction system	54	1	
Implement data reduction software	60	3	8
SIXTH YEAR			
Evaluate student performance	63	2	
Begin model design	66	2	
Refine instrumentation system	66	1	
Collect refined data	72	1	
Simulate first learning model	72	4	10

EMPIRICAL STUDY OF LEARNING

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
SEVENTH AND SUBSEQUENT YEARS			
Evaluate refined learning data		1	
Modify model design		2	
Change model simulator		2	
Correlate simulated data with observed performance		4	
Refine instrumentation system		1	10

PROFESSIONAL MANPOWER IN SUPPORT OF THE PLAN

	Effort in man-years				
	Years				
Tasks	1	2	3	4	5
Direct instruction presentation system	8	8	12	18	16
Machine independent course preparation software	12	12	16	16	14
Demonstration courses	4	8	12	16	20
Instructor's aids	6	9	14	14	14
Laboratory tools	6	9	14	14	14
Empirical study of learning	4	6	8	8	8
TOTALS	40	52	76	86	86

Chapter VII

RESEARCH IN THE INFORMATION & COMPUTING SCIENCES

Introduction

The future development of any area of knowledge is directly dependent upon current and continuing research in it and related areas. Applications of new knowledge no longer are subject to delays extending into the dim, misty, long-range future; the ability to translate new insights quickly into useful applications is now a fact of life. Thus, progress in the immediate future is heavily dependent on sustained research activities. In no area is this more true than in the information sciences.

Research in the information sciences has a different meaning and a different payoff than does research in many other professional areas. The "pure" information science researcher is interested in seeking new concepts and new data that add to our understanding of what information is, how it can be transmitted, stored and retrieved. He often is less interested in how the new knowledge may be used. This is true in most professional areas. Yet, in the information sciences, the results of a research worker's activity have very broad implications -- for all professional fields are highly dependent upon the availability and effective use of information systems. In particular, education itself is almost completely an information system. The task of educators is to increase the store of knowledge, to become more skillful in transmitting it to others, to improve the effectiveness of using existing knowledge for serving society, and to improve understanding as to how learning takes place. The ability to undertake exciting, new and relevant work in the humanities, the arts, the physical and life sciences, engineering, management, medicine, etc., is highly dependent upon research and development in the information sciences. Because of this fact, some research in the information sciences is carried on in other professional fields. Thus, important work has been done in applications of the computer sciences in engineering, in linguistics, in the behavioral sciences, etc. Nevertheless, the focus of front running research in information and computer sciences is in the small but growing group of professionals who regard themselves as information or computer scientists and who are members of the growing number of groups in universities and industry devoted to research in the computer sciences.

Research Roles[1/]

The character of computer research, as in many fields, differs with respect to scope, kind, and support (in staff and equipment) required. Important contributions can be made by one man on a small college campus -- but this is unusual. More often, outstanding research is carried on by a professor on the campus of a relatively large university working with a number of graduate students and, sometimes, a few highly selected undergraduate students. Active collaboration with other professors may also be involved. Usually the problems addressed are not only very important but are ones where the chance of visible progress by a small group in a limited time (1-3 years) is good. Research carried on by industrial organizations is necessarily closely tied to developments with neartime profit potential. It is clear that each of these sources for creative work will continue to grow in strength and productivity.

Limitations on Progress

There exist important problems in the computer sciences that both institutions of higher learning and industrial organizations cannot or do not desire to undertake. Such problems are characterized by one or more of the following conditions:

1. The time required for substantial progress is long (more than 5 years);
2. A large, full time supporting staff is necessary;
3. Very large-scale, flexible computer equipment which can be dedicated exclusively to the research must be available;
4. The research, and development activities associated with it, must have continuing access to large-scale testing.

[1/] A more detailed analysis of the strengths and weaknesses of existing computer research groups may be found in J.T. Schwartz, An Organizational Proposal for the Improvement of U.S. Computer Science. Courant Institute of Mathematical Sciences, New York University. ea. 1968.

While some individuals on the campuses of institutions of higher learning and in other organizations are interested in and capable of contributing to the solution of such problems, it seems clear that conditions do not now exist which encourage the efforts required. In fact, the very success and extraordinary growth of the computer sciences are creating service demands on both the university and other computing centers which tend to drive down much possibility of sustained research on large-scale, long-range problems. A growing awareness of the great potential value of the effective use of sophisticated computer based information systems in research, instruction and operations is bringing urgent demands for near-immediate assistance from:

The physical sciences and engineering;
The health and behavioral sciences;
The humanities and arts;
The professional schools -- medicine, law, education,
    management, etc.;
The administrators in higher education;
Community organizations -- public libraries, secondary
    schools, museums, development projects, etc.

While the growing recognition by all fields of endeavor of the importance of well designed computer based information systems is good, it does place limitations on the volume and scope of research activity which can be conducted on college and university campuses.

This chapter is devoted to a consideration of the kinds of long-range, large-scale problems in the information and computer sciences which are believed to be of great importance to many institutions of higher learning -- to many disciplines -- whose effective solutions require efforts not now under way.

Some Evident Needs

Although a variety of needs are apparent (as described in the Appendix), a few are particularly urgent from the standpoint of future progress. These are grouped according to results to be expected. The first set should lead to the development of particular systems; the second is aimed toward better understanding of fundamental techniques in the computer sciences. Both are "applied research" in the sense that they are motivated by evident requirements for the more effective use of information systems in higher education.

Systems:

1. Computer Assisted Publication System

Publication is both the culmination of old research and a genesis of new. A general purpose, computer assisted publication system would be of substantial value to researchers in all disciplines.

Professor Carl Overhage, at the Intrex Conference, described the publication process as he believed it should be.[2/] Integrated use of the computer from the first draft through editing, publication, review and retrieval is the goal. Many of the components necessary to achieve that goal have already been proven.[3/] In fact, some simpler forms of publication, such as newspapers, are already operating integrated systems.[4/] For full effectiveness, however, more complex capabilities are necessary and inter-institutional standards are highly desirable.

2. Shared, Experiment Control System

More and more experiments in the physical sciences are being controlled by on-line computers.[5/] Some would not be possible without machine aid; others are done much more effectively with it. The field is new. Sensors and effectors are usually crude. Programming is done in machine language. The machine is usually dedicated to

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2/ "The On-Line Intellectual Community" in Carl F. J. Overhage and R. Joyce Harman (editors) Intrex: Report of a Planning Conference on Information Transfer Experiments. M.I.T. Press, Cambridge, Mass. 1965. pages 25-41.

3/ Michael P. Barnett. Computer Typesetting: Experiments and Prospects. M.I.T. Press, Cambridge, Mass. 1965.

4/ Ed Yasaki. "The Computer and Newsprint". Datamation, Vol. 9, No. 3 (March 1963) pages 27-31.

5/ A. D. Smirnov. "Data Processing Systems for Physical Experiments". Proceedings of IFIP Congress 68. North Holland Publishing Co., Amsterdam. 1968. pages 236-243.

the experiment, hence it is used only in those infrequent intervals when the experiment is being run. Economics dictate the utilization of the smallest possible machine, which magnifies the programmer's problems and limits the computer's usefulness in expanding the nature of the experiments under control.

Substantial improvements are possible in many directions. The processor used in on-line control of experiments should be shared for less expense to each experiment; it could then be bigger, making it easier to use. Higher level programming languages would reduce the cost and time required to set up new experiments. Automatic timing aids should be built into the system. Sensors and effectors should be improved. Better communications can free the processor from the necessity of being located in the laboratory. Such developments have an obvious and immediate influence on many sciences.

3. Trial "Procognitive System"

The phrase "information storage and retrieval" has been so often used to mean document control that a new word is needed for the concept of researchers interacting creatively with data. J.C.R. Licklider's felicitous phrase is "procognitive system".6/ Such interactive use of computers to "promote and facilitate the acquisition, organization, and use of knowledge" can magnify human effectiveness and help lower the artificial barriers between individual researchers, their associates, laboratories and libraries. Far too little has been done in attacking such a central problem. It's obviously universal. Researchers must interact with the accumulated store of knowledge. The computer, properly programmed, can help people use and add to the collection. Clearly, the full capability described by Licklider is far in the future but substantial advances are possible now. Even tentative steps toward such a system, developed and demonstrated in specific applications, would be a valuable contribution to many fields.

6/ J.C.R. Licklider. Libraries of the Future. M.I.T. Press, Cambridge, Mass. 1965.

4. Software Systems Optimized for Educational Use

Manufacturer supplied software continues to be very poorly adapted to the needs of higher education.[7/] Furthermore, since most new software must be designed to fill the requirements of the majority of users (which are substantially different from those of college and university computing centers), the situation is unlikely to change in the foreseeable future. Recognizing this fact, many campuses have developed their own compilers and operating systems.[8,9,10/] Many of these have been outstanding accomplishments in view of the extremely limited effort spent in development. Yet, they are not experiencing widespread use, despite significant advantages, largely because limited resources make it impossible for their creators to supply the level of support which manufacturers provide with this class of software.

Locally developed software usually differs in obscure ways from the manufacturer supplied systems that students will be using after graduation; these differences further confound standardization.

Compilers and operating systems developed especially for college and university use and adequately supported by a central facility could resolve such problems at a moderate cost per institution.

7/ P.A. Samet. "Software Requirements of Universities". The Computer Journal, Vol. 11, No. 2 (Aug. 1968). pages 236-240.

8/ W. C. Lynch. "Description of a High Capacity, Fast Turnaround University Computing Center". Communications of the ACM, Vol. 9, No. 2 (Feb. 1966). pages 117-123.

9/ S. Rosen, et al. "PUFFT - The Purdue University Fast Fortran Translator". Communications of the ACM, Vol. 8, No. 11 (Nov. 1965). pages 661-666.

10/ P. W. Shantz, et al. "WATFOR - The University of Waterloo Fortran IV Compiler". Communications of the ACM, Vol. 10, No. 1 (Jan. 1967). pages 41-44.

5. Computer Effectiveness Metering System

The extremely high demand for computing service, coupled with frequently severe restrictions on funds available, make imperative the fullest practicable efficiency in operating the campus computer center. Yet, all too often, the same combination limits attention that center personnel can devote to this essential function. The result is that some of the most overloaded computers can be the least efficiently run; new machines may be acquired when spare capacity is still available in the old.

New computer system metering techniques are possible which measure the effectiveness of a machine during operation.[11/] Supported with analysis software and a specialized staff, such measurements can lead to minor system changes which can have major results. Unfortunately, such techniques have been limited to in-plant use by a few manufacturers. The tool should be more fully developed for a variety of computers and made available widely to college and university computing center directors.

Techniques:

1. Natural Language "Comprehension" Techniques

Much symbol manipulation still being done by man could be performed by machines. Translators for converting natural language into a formal representation and back again would be a big help in transferring concepts between man and machines. To be sure, what the man meant to say will not always be "understood" by the machine. Making a machine "comprehend" free human discourse is probably impossible. People can't even do it. We use conversation for the mutual exploration of concepts until

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11/ D. J. Campbell and W. J. Heffner. "Measurement and Analysis of Large Operating Systems During System Development". AFIPS Conference Proceedings, Vol. 33, Part 1 Thompson, Washington, D.C. 1968. pages 903-914.

they conform. If we expect machines to "understand" our concepts, then we should expect to converse with them. Machine "comprehension" may always be limited, but people are smart; we will learn how to adapt our discourse to minimize the effect of the computer's limitations.

Once concepts are in the machine, we want to be able to manipulate them. Many operations now done by people can be done faster, cheaper and more accurately by computers. Such developments as the various mathematical manipulators are steps in the right direction. They need to be coordinated, expanded and extended to handle routine operations of other disciplines. Much thinking, for example, devolves around relationships. We should have general tools for processing hierarchical structures.

We don't want to have to tell the computer all the details of a process. Certain things should be taken for granted. When receiving new concepts, for example, the computer should continually check the logical consistency of new assertions with those it already has. When an inconsistency is found, we expect to be told about it. For, in this fashion, we can be sure that we are not inadvertently violating our own rules of inference.

2. Data Management Techniques

Data is the common component of all computer use. The costs of collecting, converting, validating, storing and retrieving computer based information frequently dominate the total cost of mechanization. Yet, very little aid has been provided to help a programmer manage data efficiently. As a result, one installation found that, despite strident demands for more bulk storage, only one percent of its existing capacity was being utilized; off-the-record discussions with other computer center managers suggest that such use is the rule rather than the exception! 12/ Contrast this situation with the many valuable aids programmers have for efficient algorithm construction.

12/ Dwight Ashley. Personal Communication. 1965.

Some advances are beginning to be made. For example, S.P. Ghosh has recently shown how finite mathematics can be used to organize simple formatted files to answer different classes of queries in the shortest possible time.[13/] Additional research, particularly into techniques for automatically providing optimized storage structures, could benefit a large number of campus computer users.

3. Man-Machine Interface Techniques

The connection between the man and the machine is a highly specialized communication channel which must be adapted to the individual's unique strengths and weaknesses. In an ideal system, all of man's senses should be used to absorb information about the state of the system and each of his effectors should be usable for control.[14/] Existing man-machine interfaces are a long way from that achievement.[15/] In fact, we have barely begun to discover efficient ways to couple the two into an effective partnership. Much work is needed to determine what is possible. Much more application of these techniques to real problems is necessary to decide what is desirable.

The computer should be able to create an environment expressing its abstract world in man's concrete terms. The abstraction in the computer may correspond to no real world. But, through analogy, a person's powerful intuition could be brought into effective use. The machine should also be able to sense man made changes in that environment and convert these into its corresponding abstractions so the powers of each can be brought to bear on the same problem.

[13/] S. P. Ghosh. "On the Problem of Query Oriented Filing Schemes Using Discrete Mathematics". Proceedings of IFIP Congress 68. North Holland Publishing Co., Amsterdam. 1968. pages F74-F79.

[14/] Ivan E. Sutherland. "The Ultimate Display". Wayne A. Kalenich (editor) Proceedings of IFIP Congress 65, Vol. 2. Spartan Books, Washington, D.C. 1966. pages 506-508.

[15/] Ivan E. Sutherland. "A Head-Mounted Three Dimensional Display". AFIPS Conference Proceedings, Vol. 33, Part 1. Thompson, Washington, D.C. 1968. pages 757-764.

Research Leading to New and Advanced Computer Systems

The large-scale computer has developed very rapidly over the last two decades. Results of research in the physical sciences and in engineering have led to smaller, faster, less costly and more reliable components. New and effective ways of linking such components in the design of a large computer have been developed but a computer system consists of much more than an interconnection of basic components. System software, which establishes the possible relationships which can exist between various machine components, is of key importance to successful operation. Its design is extremely difficult and the methods for pursuing such designs leave much to be desired. Another aspect of overall computer systems design is the nature of the application software -- the programs by which a wide variety of users employ the computing system to solve problems of interest to them. Here again, the design of such programs and their utilization is difficult. The total success of a computer system depends upon how well all three areas of design are executed and interrelated. Clearly, more effective computer systems will result when a new system can be created by a nearly simultaneous and interrelated development of all three aspects. Obviously, this is a tremendously complex task and one that requires a long-range, large-scale research program over an extended period of time.

At the present time there appears to be no effective action directed toward the goal outlined above. It is clearly an objective which can only be approached -- never reached. It is a task which requires large-scale, flexible equipment, extraordinarily talented people and an outstanding supporting staff all dedicated to the conduct of research aimed at establishing a better framework for computer systems design. The environment must be one in which the research work is freed from considerations of service to other professional fields. It must be one which is not tied to specific applications which represent the large volume of users. It must be one where the requirements of compatibility with existing applications software does not provide severe constraints. It must be one where established hardware design philosophy is not restricted.

The establishment of such an environment or environments is important to the future of computing science and to the growing world of users from all disciplines. The lessons of the past and present seem to indicate this is too large, too long-range, too expensive a task for any single university to undertake. In addition, the results of efforts of this kind which might be undertaken by industrial organizations are not made generally available to all interested parties.

Conclusion

Increased effort in two types of research are recommended.

1. Applied research leading to the development of specific systems whose use would be of major importance to many institutions.

2. Research aimed at the better understanding of how to design extremely complex computer systems.

Progress in this area would have an important influence on the design of all complex systems whether they were computer based or not.

APPENDIX

ESTIMATED TIME AND COSTS OF SOME LARGE-SCALE RESEARCH PROJECT OPTIONS

Summary of Options

	Calendar Year					
Option - Level of Effort in Man-Years	1	2	3	4	5	6
SYSTEMS DEVELOPMENT						
1. Applications						
Computer assisted publication	20	24	30	20	12	12
Natural language processing	16	16	19	20	16	10
Shared experiment control	25	40	50	40	30	30
Trial "precognitive" system	10	14	18	22	17	17
Trial speech recognizer	24	26	28	22	16	16
2. Software						
Extensible programming language	12	15	18	18	12	10
Operating system for education	32	44	50	50	49	48
Programming language for education	16	22	26	30	30	30
Programming language for on-line control	10	12	12	12	8	5
3. Operations						
System effectiveness metering	16	16	18	20	17	17
TECHNIQUES RESEARCH						
1. Applications						
Educational systems modeling	9	12	15	18	21	21
Natural language "comprehension"	8	10	12	14	16	16
2. Software						
Data management	5	6	7	9	11	11
Software production	15	19	23	27	29	29

Option - Level of Effort in Man-Years	Calendar Year 1	2	3	4	5	6
TECHNIQUES RESEARCH continued						
3. Operations						
Computer effectiveness	14	18	21	24	27	27
Resource file	12	13	14	15	16	16
4. Interface						
Inter-computer communication	10	13	16	18	20	20
Machine-environment	12	15	19	22	25	25
Man-machine	10	14	18	21	24	24

Computer Assisted Publication Facility

Objective: To design, produce, demonstrate and make available an integrated system for computer assistance to the publication process from the first draft to the final printed copies.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	4	
Survey available hardware	12	2	
Survey relevant software	12	4	
Preliminary system design	12	10	20
SECOND YEAR			
Prepare detailed specifications	15	6	
Circulate specifications to community for comment	18	0	
Establish criteria for selection	18	3	
Revise specifications	21	3	
Prepare software modules	24	12	
Solicit competitive bids for hardware	24	0	24
THIRD YEAR			
Evaluate proposals	27	6	
Order hardware	27	0	
Prepare training materials	36	4	
Train experimental users	36	2	
Integrate software modules	36	15	
Install hardware	36	3	30

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FOURTH YEAR			
Limited operation for evaluation	42	4	
Design necessary changes	42	4	
Revise detailed specifications and training materials	42	4	
Integrate design changes	48	6	
Publish specifications and manuals	48	2	20
FIFTH AND SUBSEQUENT YEARS			
Full scale operation of system		4	
System maintenance and improvement		6	
Advisory and training services		2	12

Natural Language Processing Facility

Objective: To design, construct and deliver a facility directed toward meeting the needs of humanists for research using works written in natural languages.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	4	
Survey technology	6	4	
Design experimental system	12	8	16
SECOND YEAR			
Circulate design to community for comment	15	0	
Prepare detailed specifications	15	4	
Revise specifications	18	4	
Prepare software modules	24	8	16
THIRD YEAR			
Implement experimental system	30	8	
Validate experimental system	36	6	
Draft primer and reference manuals	36	4	
Train experimental users	36	1	19
FOURTH YEAR			
Experimental system evaluation	42	4	
Design operational system	42	8	
Prepare software modules	48	8	20

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIFTH YEAR			
Implement operational system	54	8	
Validate operational system	60	4	
Complete and publish manuals	60	4	16
SIXTH AND SUBSEQUENT YEARS			
Operations		2	
Advisory service		4	
Maintenance and improvements		4	10

Shared, Experiment Control System

Objective: To design, construct, demonstrate and make available an integrated hardware-software system which can control a number of independent experiments simultaneously on shared equipment.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	5	
Survey technology	6	5	
Initial design	12	15	25
SECOND YEAR			
Circulate initial design to community for comment	15	0	
Prepare detailed specifications	18	15	
Solicit competitive bids for hardware	21	0	
Establish criteria for selection of hardware	21	5	
Evaluate proposals	24	5	
Order hardware	24	0	
Prepare software modules	24	15	40
THIRD YEAR			
Install hardware	30	5	
Complete software	30	25	
Validate system	36	15	
Draft documentation	36	5	50

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FOURTH YEAR			
Train experimental users	39	5	
Test preparation	48	10	
Test evaluation	48	10	
Experimental operation	48	5	
Revise specifications	48	5	
Complete documentation	48	5	40
FIFTH AND SUBSEQUENT YEARS			
Test preparation and evaluation		15	
Design changes and improvements		10	
Advisory services		3	
Maintenance		2	30

Trial "Procognitive" System

Objective: To design, construct and test a first approximation to a machine assistant to researchers as postulated by J.C.R. Licklider in Libraries of the Future.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	2	
Survey technology	6	2	
Initial design	12	6	10
SECOND YEAR			
Circulate initial design to community for comment	15	0	
Prepare detailed specifications	24	12	
Solicit competitive bids for hardware	24	0	
Select system test problems	24	2	14
THIRD YEAR			
Establish criteria for selection	27	2	
Evaluate proposals	27	2	
Order hardware	27	0	
Prepare software modules	36	10	
Draft primer and reference manuals	36	4	18
FOURTH YEAR			
Install hardware	39	2	
Integrate software modules	42	10	
Validate integrated system	48	6	
Publish manuals	48	2	
Train experimental users	48	2	22

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIFTH AND SUBSEQUENT YEARS			
Experimental use		10	
System maintenance and improvement		5	
Advisory service and training		2	17

Trial Speech Recognition Facility

Objective: To design and construct the best currently practicable speech recognition facility and to evaluate its merits and shortcomings in a variety of educational applications.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	4	
Survey technology	6	8	
Initial design	12	12	24
SECOND YEAR			
Circulate initial design to community for comment	15	0	
Select test problems for system	15	6	
Prepare detailed specifications	18	6	
Solicit competitive bids for hardware	21	0	
Establish criteria for selection of hardware	21	2	
Evaluate proposals	24	2	
Order hardware	24	0	
Prepare software modules	24	10	26
THIRD YEAR			
Install hardware	30	2	
Complete software	30	10	
Design tests	30	4	
Validate system	36	10	
Draft documentation	36	2	28

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FOURTH YEAR			
Experimental operation	42	4	
Test preparation	42	8	
Test evaluation	45	4	
Revise specifications	48	4	
Complete documentation	48	2	22
FIFTH AND SUBSEQUENT YEARS			
Test preparation and evaluation		6	
Design changes and improvements		6	
Advisory services		2	
Maintenance		2	16

Extensible Programming Language Facility

Objective: To design, construct and deliver a machine-independent programming language (with the requisite translators and documentation) which expedites its own extension for adaptation to new applications.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	3	
Survey technology	6	3	
Design experimental system	12	6	12
SECOND YEAR			
Circulate specifications to community for comment	18	0	
Select a computer for initial implementation	18	2	
Revise specifications	24	3	
Prepare software modules	24	10	15
THIRD YEAR			
Implement experimental system	30	10	
Experimental operation and evaluation	36	5	
Draft primer and reference manuals	36	3	18
FOURTH YEAR			
Produce specifications for operational system	39	6	
Implement operational system	48	10	
Revise documentation for operational system	48	2	18

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIFTH YEAR			
Validate operational system	54	6	
Design, implement and demonstrate extensions	60	4	
Advisory service		1	
Maintenance		1	12
SIXTH AND SUBSEQUENT YEARS			
Design, implement and demonstrate extensions		6	
Advisory service		2	
Maintenance		2	10

Operating System Optimized for Educational Use

Objective: To design, construct and deliver a machine-independent operating system (with the requisite software and documentation) which is optimized for use in higher education. The operating system software will be designed for economical mass-production for all machines in the educational community.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	8	
Survey available technology	6	8	
Preliminary control language and capabilities design	12	16	32
SECOND YEAR			
Circulate specifications to community for comment	15	0	
Survey desirable computers for implementation	18	8	
Select method of implementation	18	2	
Preliminary operating system design	21	12	
Revise control language and capabilities design	24	8	
Draft control language and capabilities reference manual and primer	24	8	
Design experimental system	24	6	44
THIRD YEAR			
Circulate draft primer and reference manual to community for comments	30	0	
Prepare experimental system	30	15	
Evaluate experimental system	36	15	

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
THIRD YEAR continued			
Revise specifications for first operational system	36	10	
Revise primer and reference manual	36	5	50
FOURTH YEAR			
Prepare software modules	42	20	
Produce first operational system	48	25	
Revise and publish documentation	48	5	50
FIFTH YEAR			
Validate first operational system	54	15	
Distribute first system with documentation	54	5	
Produce second system	54	10	
Validate second system	60	10	
Distribute second system	60	3	
Advisory services		4	
Maintenance		2	49
Nth YEAR (N ≥ 6)			
Produce 4(N-6) + 3rd system	12(N-1)+3	5	
Validate 4(N-6) + 3rd system	12(N-1)+6	3	
Distribute 4(N-6) + 3rd system	12(N-1)+6	2	
Produce 4(N-6) + 4th system	12(N-1)+6	5	
Validate 4(N-6) + 4th system	12(N-1)+9	3	
Distribute 4(N-6) + 4th system	12(N-1)+9	2	
Produce 4(N-6) + 5th system	12(N-1)+9	5	
Validate 4(N-6) + 5th system	12N	3	
Distribute 4(N-6) + 5th system	12N	2	
Produce 4(N-6) + 6th system	12N	5	
Validate 4(N-6) +6th system	12N + 3	3	
Distribute 4(n-6) + 6th system	12N + 3	2	
Advisory services		5	
Maintenance		3	48

Programming Language and Translator Optimized for Educational Use

Objective: To design, construct and deliver a machine-independent programming language (with the requisite translators and documentation) which is optimized for use in higher education. The translators will be designed for economical mass-production for all machines in the educational community.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	4	
Survey available technology	6	4	
Preliminary language design	12	8	16
SECOND YEAR			
Circulate language specifications to community for comment	15	0	
Survey desirable translating and target computers	18	4	
Preliminary translator design	18	4	
Revise language specifications	24	4	
Draft language primer	24	2	
Draft reference manual	24	2	
Prepare experimental translator	24	6	22
THIRD YEAR			
Circulate draft primer and reference manual to community for comment	30	0	
Evaluate experimental translator	30	4	
Revise translator specifications	30	4	
Prepare software modules	36	12	
Revise primer and reference manual	36	4	
Prepare translator maintenance manual	36	2	26

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FOURTH YEAR			
Produce first operational translator	42	12	
Validate first translator	48	6	
Produce second translator	45	6	
Validate second translator	48	3	
Distribute first two translators with documentation	48	3	30
Nth YEAR ($N \geq 5$)			
Produce 4(N-5) + 3rd translator	12(N-1)+3	3	
Validate 4(N-5) + 3rd translator	12(N-1)+3	2	
Distribute 4(N-5) + 3rd translator	12(N-1)+6	1	
Produce 4(N-5) + 4th translator	12(N-1)+6	3	
Validate 4(N-5) + 4th translator	12(N-1)+9	2	
Distribute 4(N-5) + 4th translator	12(N-1)+9	1	
Produce 4(N-5) + 5th translator	12(N-1)+9	3	
Validate 4(N-5) + 5th translator	12N	2	
Distribute 4(N-5) + 5th translator	12N	1	
Produce 4(N-5) + 6th translator	12N	3	
Validate 4(N-5) + 6th translator	12N+3	2	
Distribute 4(N-5) + 6th translator	12N+3	1	
Advisory services		4	
Maintenance		2	30

Programming Language for On-Line Control

Objective: To design, construct, demonstrate and make available a programming language and translator which is particularly adapted to the on-line control of experiments.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	2	
Survey technology	6	3	
Initial design	12	5	10
SECOND YEAR			
Circulate initial design to community for comment	15	0	
Coordinate with Shared, Experiment Control System development	15	3	
Revise initial design specifications	18	2	
Prepare software modules	24	7	12
THIRD YEAR			
Implement initial translator	30	6	
Validate initial translator	36	4	
Draft documentation	36	2	12
FOURTH YEAR			
Produce specifications for operational translator	39	3	
Implement operational translator	48	5	
Complete documentation	48	2	12

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIFTH YEAR			
Validate operational translator	54	5	
Advisory service		2	
Maintenance		1	8
SIXTH AND SUBSEQUENT YEARS			
Maintenance and improvements		3	
Advisory service		2	5

Computer System Effectiveness Metering Facility

Objective: To design, construct, demonstrate and make available a general-purpose, integrated, hardware-software facility for measuring the operational effectiveness of computing systems.

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIRST YEAR			
Establish requirements	6	3	
Survey technology	6	5	
Initial design	12	8	16
SECOND YEAR			
Circulate initial design to community for comment	15	0	
Prepare detailed specifications	24	16	
Solicit competitive bids for hardware	24	0	16
THIRD YEAR			
Establish criteria for selection	27	2	
Evaluate proposals	27	2	
Order hardware	27	0	
Prepare software modules	36	10	
Draft primer and reference manuals	36	4	18
FOURTH YEAR			
Install hardware	39	4	
Integrate software modules	39	9	
Validate integrated system	48	5	
Publish manuals	48	2	20

Task	Available after (calendar months)	Effort in man-years	Level of Effort in man-years
FIFTH AND SUBSEQUENT YEARS			
Operate metering system at centers requesting the service		5	
Data reduction		4	
System maintenance and improvement		6	
Advisory service		2	17

Higher Educational Systems Modeling and Simulation Studies

Objective: To examine the structure of institutions of higher education through modeling, simulation and validation studies in order to assist administrative decision making.

Specialist Title	Level of Effort In the Speciality
Experienced administrators	2
Operations researchers	4
Mathematicians/Statisticians	2
Programmers	6
Researchers	2
Support personnel	5
TOTAL man-years per year	21

Natural Language "Comprehension" Studies

Objective: To investigate techniques which might permit machine "comprehension" of statements made in natural languages.

Specialist Title	Level of Effort In the Speciality
Mathematical linguists	2
Linguists	4
Programmers	6
Support personnel	4
TOTAL man-years per year	16

Data Management Studies

Objective: To collect, create, test and evaluate techniques for the acquisition, structuring, storage, retrieval and disposition of large data files.

Specialist Title	Level of Effort In the Speciality
Computer scientists	4
Programmers	2
Researchers	2
Support personnel	3
TOTAL man-years per year	11

Software Production Techniques

Objective: To design, implement, utilize and make available techniques for the more economical development and production of software.

Specialist Title	Level of Effort In the Speciality
Computer scientists	7
Industrial engineers	5
Programmers	10
Support personnel	7
TOTAL man-years per year	29

Computer System Effectiveness Studies

Objective: To evaluate the effectiveness of hardware, software and operating doctrine in existing and proposed educational computing centers.

Specialist Title	Level of Effort In the Speciality
Computer scientists	2
Engineers	5
Systems programmers	5
Programmers	3
Mathematicians/Statisticians	2
Operators	3
Support personnel	7
TOTAL man-years per year	27

Educational Community Computing Resources File

Objective: To maintain an accurate, current and detailed file of the hardware and software resources of the nation's educational community in support of multi-machine projects at the center but available to all interested parties.

Specialist Title	Level of Effort In the Speciality
Researchers	4
Programmers	2
Support personnel	10
TOTAL man-years per year	16

Inter-Computer Communication Studies

Objective: To collect, create, test and evaluate techniques for the inter-connection of computer systems.

Specialist Title	Level of Effort In the Speciality
Computer scientists	5
Communications engineers	5
Programmers	3
Researchers	2
Support personnel	5
TOTAL man-years per year	20

Machine-Environment Interface Enhancement

Objective: To design, produce, test and make available equipment and techniques for improved coupling between computers and the environment.

Specialist Title	Level of Effort In the Speciality
Computer scientists	5
Engineers	
Hybrid equipment	5
Communications	2
Programmers	7
Support personnel	6
TOTAL man-years per year	25

Man-Machine Interface Enhancement

Objective: To design, construct, test and evaluate equipment and techniques which enhance the opportunities for constructive interaction of men and machines for problem solving.

Specialist Title	Level of Effort In the Speciality
Computer scientists	5
Engineers	
Display	3
Hybrid equipment	2
Communications	1
Psychologists	2
Programmers	5
Support personnel	6
TOTAL man-years per year	24

Chapter VIII

THE COMPUTER IN THE LIBRARY

Introduction

> By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is spoken of as "known", and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory.
>
> ...Lord Rayleigh, 1884

Today -- even more than in Lord Rayleigh's time -- researchers tend to "give up" on their responsibility to "keep up" with the literature. For although the cost of "discovery in the laboratory" has increased enormously, the exponential growth of publication has overwhelmed conventional library reference tools.

Many projects are under way (Appendix 1) that use a computer to shift the balance toward economic "rediscovery in the library". Almost all are worthwhile and deserve continued support. Yet, despite the diversity, a major effort devoted to bringing the best of proven technology to a large number of college and university libraries is lacking. We shall, therefore, examine the feasibility of attaining this specific goal. In the process, we shall propose an opportunity and a program leading to a substantial advance in library automation at a fundable cost. The result is not -- to be sure -- the final answer to Lord Rayleigh's implicit challenge but it is within the immediate reach of existing knowledge and equipment.

Objectives

Effective knowledge is the right thought in the prepared mind at the critical instant. Two of mankind's greatest inventions -- the alphabet and printing -- make possible an enormously valuable store of information. Libraries bring this accumulation of millennia together for the common welfare. Today many scholars have access -- at least in principle -- to the printed words of many minds.

The practice of making the key portion of the world's accumulated knowledge available to each individual who needs it, when he needs it, at an acceptable cost has become enormously important but increasingly difficult. Important information is dispersed throughout the world. Existing knowledge has swamped available techniques; yet, new information continues to be generated at an accelerating rate. Thus, in actuality, it has become nearly impossible for a worker to assess all the existing information of value in his particular field.

The rapidly developing technology of the computer and worldwide communications systems makes new approaches possible. Such developments can lead to important new characteristics of a library system. For example, on-line interaction between researchers and a computer based library system permits insertion as well as extraction of information, a process that can accelerate collaborative undertakings and reduce overlapping research activities.

The potential is great but the difficulties in realizing it are substantial. These include:

1. No catalog system exists, even conceptually, which makes it possible to know most of the information important to a given subject area. This problem is increasing in difficulty for it is clear that work in one subject area often has important implications in apparently unrelated areas.

2. An ideal, long-range library development must be worldwide in its scope -- at minimum it must encompass the nation. Hence efforts must be large-scale and must involve the cooperative efforts of many people and organizations.

3. A large and continuing education program in information and computer science and technology for people who staff libraries is needed.

4. The existing library resources need to be used more effectively by many more people while quite different systems of library design and operation are considered and developed for the future.

Measured against the enormity of the total library task required, the "RULAS" program, whose feasibility is studied in this chapter, appears to have a very limited objective. Nevertheless it is an evident beginning which faces a number of these critical obstacles.

A World Library

The idea of a world library is an old[1/] and continuing dream.[2,3,4,5,6,7,8/] With it, "if a potential user desires to have a copy of something that exists in a library, no matter where, in the interest of the advance of knowledge it should be furnished to him without charge."[6/] Regrettably, this is still only a dream. Progress is being made through microforms, new copying techniques, union catalogs and inter-library loans but practical realization of the goal is a long way away.

Users are convinced that easy access to the world's store of 500 million unique titles[9/] could benefit scholars enormously. Librarians are committed; they embody one of civilization's earliest and most effective examples of resource sharing. Why must we wait?

1/ H. G. Wells, World Brain. Doubleday, Doran and Co., Garden City, N.Y. 1938.

2/ Vannevar Bush. "As We May Think". Atlantic Monthly, Vol. 176, No. 1 (July 1945), pages 101-108.

3/ Alvin Weinberg, et al. Science, Government and Information. The White House, Washington, D.C. 1963.

4/ Charles Van Doren. "The Idea of an Encyclopedia". American Behavioral Scientist, Vol. 6, No. 1 (September 1962), pages 23-26.

5/ Gilbert W. King, et al. Automation and the Library of Congress. Library of Congress, Washington, D.C. 1963.

6/ Watson Davis. "The Universal Brain: Is Centralized Storage and Retrieval of All Knowledge Possible, Feasible, or Desirable?" Address before the National Microfilm Association Meeting at Cleveland, Ohio, on May 13, 1955. Reprinted in Manfred Kochen (editor) The Growth of Knowledge. Wiley, New York. 1967.

7/ Vannevar Bush. "Memex Revisited." Science Is Not Enough. William Morrow & Co., New York. 1967. pages 75-101.

8/ J.C.R. Licklider. Libraries of the Future. M.I.T. Press, Cambridge, Massachusetts. 1965.

9/ John W. Senders. "Information Storage Requirements for the Contents of the World's Libraries". Science, Vol 141 (13 September 1963), pages 1067-1068. (1958 data has been extrapolated to 1969 at the 3.1% growth per year estimate in the article.)

Without minimizing in any way the profound conceptual problems to be solved, the primary deterrent is cost. To be sure, libraries collectively in the U.S. probably spend several billion dollars each year; yet, very little goes into research and development. Precise data are hard to obtain. Judging by the modest impact of new technology on libraries, however, the amount spent on innovation is clearly inadequate. Until the situation changes substantially, it is unrealistic to expect significant changes in the way libraries operate.

Even with ample R&D funds, a single "great leap forward" to a world library would be unsound. Each step should be able to demonstrate its worth in lowered costs or greater effectiveness. Yet, if we are to reach our goal in this century, substantial advances are necessary.

Better access to library files is a demonstrable need. The computer is an important tool to provide the enhanced access. Major improvements are attainable without further technological breakthroughs and can be independent of advances in other areas. Furthermore, through proper design, the system can be kept general-purpose and open-ended. No options need be closed. On the contrary, many new opportunities will be opened through the widespread availability of computing in many libraries.

For greater practicability, the initial system (although designed for a large number of libraries) should be implemented for a reasonably compact group of relatively advanced users. U.S. college and university libraries are a particularly attractive possibility.

College and University Libraries

The library is an essential -- and expensive -- component of campus life. Its importance is too evident to require defense. In our increasingly complex world, the library's role as the agent for sharing the world's store of published information must continue to grow. To fill the need, U.S. college and university libraries are spending about a half billion dollars this year (Figure 1) and the amount is doubling every five years. The number of volumes held has already passed 300 million (Figure 2) and is doubling every seven years.[10/] Yet, according to the same U.S. Office of Education

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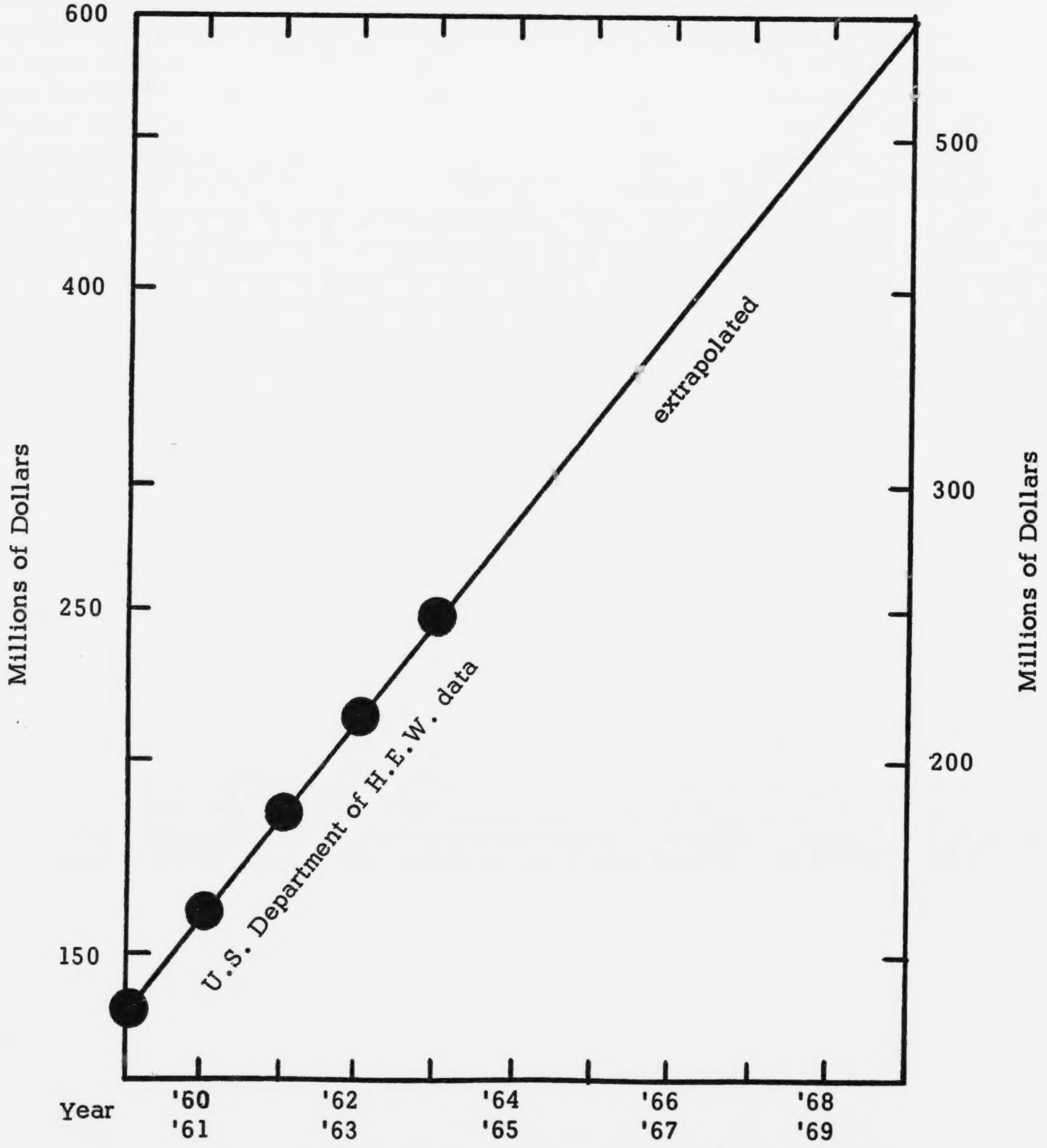
[10/] Theodore Samore. Library Statistics of Colleges and Universities, 1963-64: Analytic Report. U.S. Dept. of H.E.W., Washington, D.C. 1968.

Figure 1

The Growth of
U.S. College and University Libraries
Annual Operating Expenditures

(logarithmic scale)



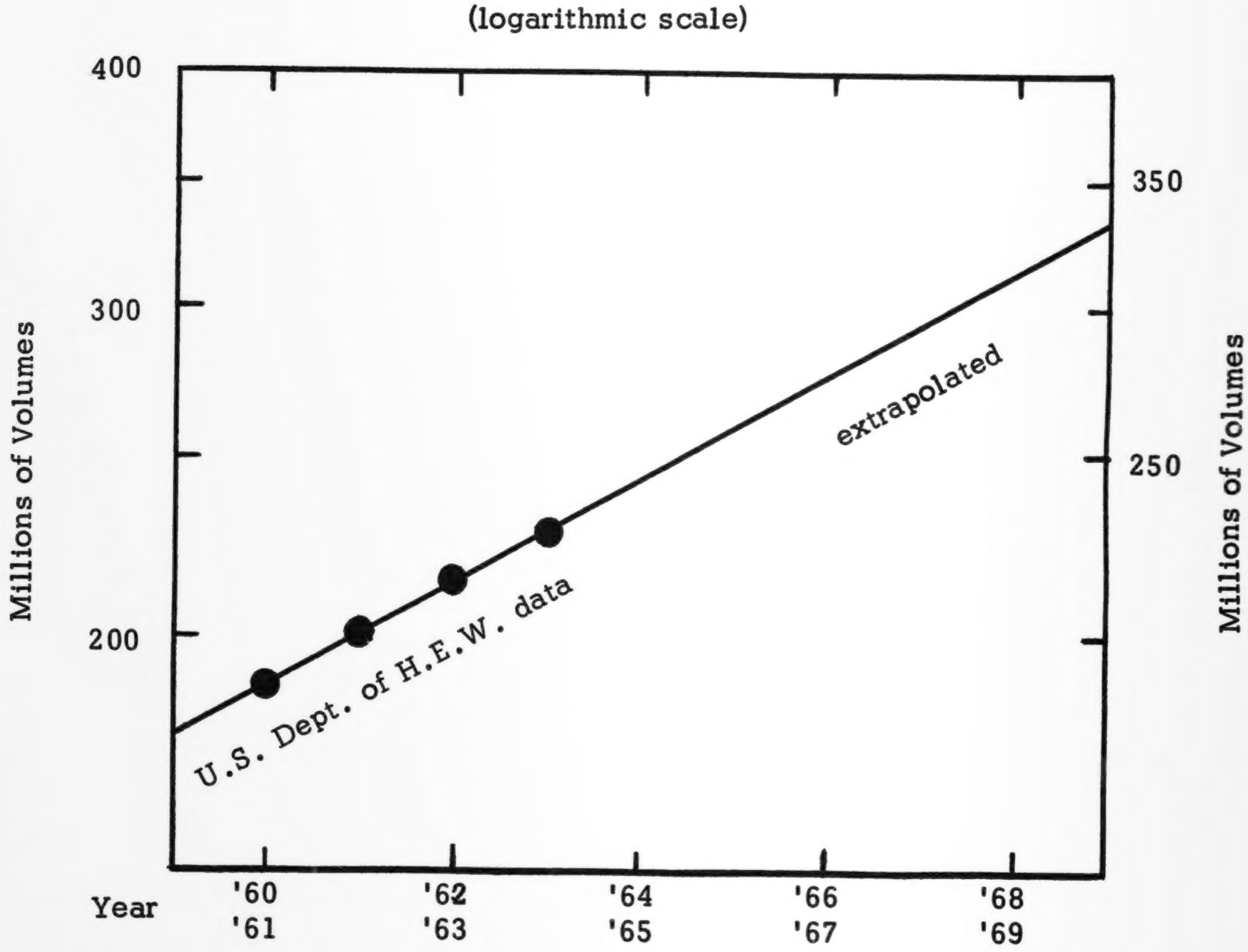
Source: Theodore Samore. Library Statistics of Colleges and Universities, 1963-64: Analytic Report. U.S. Office of Education, Washington, D.C. 1968.

Figure 2

The Growth of

U.S. College and University Libraries

Number of Volumes



Source: Theodore Samore. Library Statistics of Colleges and Universities, 1963-64: Analytic Report. U.S. Office of Education, Washington, D.C. 1968.

Report, "academic libraries are being hard put to maintain even present levels of library resources and services." Clearly, they need help.

Can computers help? In a report to the Librarian of Congress, Gilbert W. King, et al, concluded:5/

> The immediate objective of automation will be to solve the pressing problems that face research libraries, among which are problems of bibliographic organization and control. In the long run, however, the most significant effect of automation will be the focusing of the services of the library on the individual user for the optimal satisfaction of his research needs. Ideally an automated system should place the full resources of the library at the immediate disposal of the user. These resources should be more varied in nature and contain a much richer set of statistical and bibliographical data than it is practical to provide in conventional libraries. The services of reference librarians can be greatly extended in those areas where the fallibility and limit of human memory are a barrier to providing information that the user needs. At the same time our relatively scarce resources in terms of expert reference librarians will be better utilized in those areas where human judgment and intellect can provide services beyond the capabilities that can be supplied by a mechanized system.

This paper is an investigation of how some of these benefits might be brought to many college and university libraries in the near future.

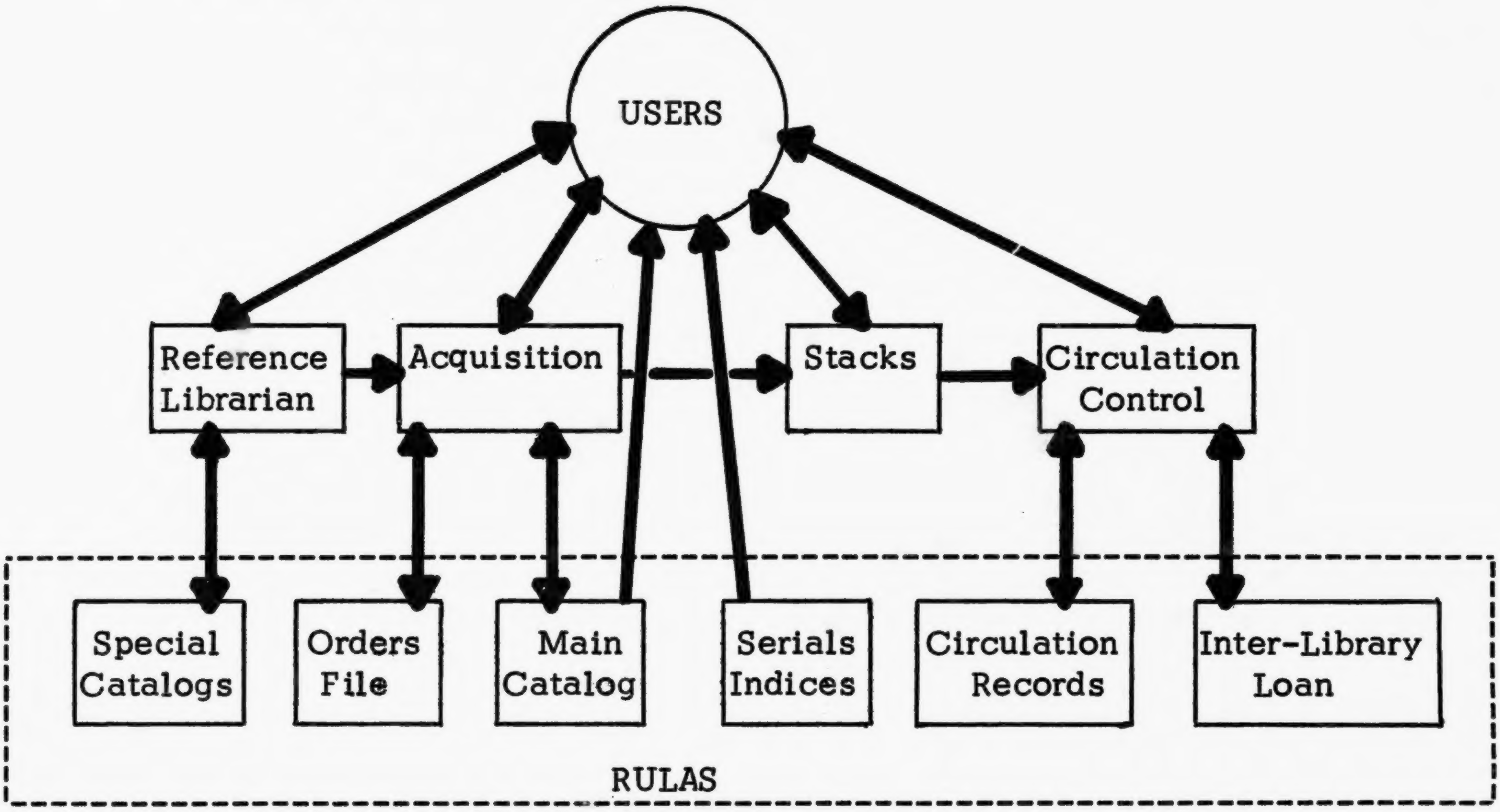
Information Flow in the Library

Libraries are proven information transfer systems; they have evolved over an extended period to meet, with largely manual procedures, the needs of users. Automation may change how things are done but it should begin with an understanding of why they are done. To this end, we present a simplified model of the principal paths of information flow within a typical academic library (Figure 3).

5/ See footnote, page 3.

Figure 3

INFORMATION FLOW IN THE LIBRARY
(A Simplified Model)


USERS
Reference Librarian
Acquisition
Stacks
Circulation Control
Special Catalogs
Orders File
Main Catalog
Serials Indices
Circulation Records
Inter-Library Loan
RULAS

Users -- the library's principal reason for being -- occupy a central role in the information transfer process. Normally, needs are filled by routine reference to card catalogs, various review journals and other finding aids (such as the Reader's Guide to Periodical Literature), followed by acquisition of desired documents through circulation control from either local stacks or through inter-library loan. Occasionally, additional assistance is obtained from professional librarians, who use their knowledge of library procedures and special catalogs to solve particularly difficult problems. Some users help keep the collection responsive to changing needs by recommending new acquisitions.

To serve the users -- both present and future -- libraries need a number of other files. Circulation, for example, must be able to locate all borrowed material. Acquisition needs price lists and records of transactions with booksellers. Reference librarians use (and often create) specialized catalogs to help them operate effectively.

The limitations of manual methods tend to keep the various files separate. Yet, much of the material they maintain is duplicated. With a computer to help process the desired information in ways responsive to each person's needs, consolidation becomes possible. This not only saves storage costs, it also makes feasible the dedication of a portion of the machine's power to improving the effectiveness of other library functions. We shall call this concept of a common file, accessed through specialized capabilities for each class of user, unified library automation.

Unified Library Automation

A basic question posed by everyone in the library is "where can I locate..." The skill and motive behind the question vary. A borrower wants to know if an answer to his question exists in print and how he can obtain a copy. Circulation wants to account for each volume. Acquisition and Inter-Library Loan want to extend the collection, permanently or temporarily. Unified library automation is a single system to meet many of these needs. The base is a complete, on-line, inventory control system with access capabilities tailored to each individual use. In brief, it is an extension of proven technology (e.g., airline reservation systems) to meet library needs.

Needless to say, there is nothing new in the concept.[8,11,12,13,14,15,16/] One feasibility study, however, discovered that the price of an on-line computer and files is too high for five Washington, D.C., university collections[17/] totaling 2.6 million volumes. Since the pro rata shared costs will decrease with increasing collections (Appendix 2), we shall examine costs for a system that is an order of magnitude larger -- one that contains approximately one-tenth of the nation's college and university library resources. In so doing, we shall discover that such a system can be both practicable and economic.

Our objective is access to the nation's library resources for everyone in higher education on an economically self-sustaining basis with the next decade. The approach is the development of a "Regional, Unified Library Automation System", called RULAS, which can be replicated to fill important national needs. A principal requirement is that the system be within the means of virtually the smallest library and that it provide improved service even to the largest. Development is assumed by a dedicated

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8/ See footnote, page 3.

11/ N.S.M. Cox, J.D. Dews and J.L. Dolby. The Computer and the Library. Archon Books, Hamden, Connecticut. 1967.

12/ Barbara Evans Markuson. "Automation in Libraries and Information Centers." Annual Review of Information Science and Technology, Volume 2. Wiley, New York. 1967.

13/ Donald V. Black and Earl A. Farley. "Library Automation." Annual Review of Information Science and Technology, Volume 1. Wiley, New York. 1966.

14/ Frederick G. Kilgour. Initial System Design for the Ohio College Library Center: A Case History. Presented at the Sixth Annual Clinic on Library Applications of Data Processing, University of Illinois. 7 May 1968.

15/ William R. Nugent. "NELINET - The New England Library Information Network." Proceedings of IFIP Congress 68. North Holland Publishing Co., Amsterdam. 1968.

16/ Carl F. J. Overhage and J. Francis Reintjes. "Information Transfer Experiments at M.I.T." Proceedings of IFIP Congress 68. North Holland Publishing Co., Amsterdam. 1968.

17/ Ralph Parker. A Feasibility Study for a Joint Computer Center for Five Washington, D.C. University Libraries: Final Report. Consortium of Universities of Metropolitan Washington, D.C. May 1968.

group which is adequately funded to perform all tasks of universal applicability, augmented by decentralized, locally funded effort to meet the needs of the individual libraries. Participation in RULAS is intended to be completely voluntary; the system is designed to succeed by being better than a library can afford to develop for itself. Finally, at the completion of the development period, the entire cost of using and extending RULAS will be funded by service charges for its use. These annual charges can be significantly less than the cost of one book per library user.

Using RULAS

Imagine a user entering a library after RULAS has been installed. Mr. Jones goes into the catalog room; the card files are gone but a number of consoles are in their place. His search is to be brief, so he chooses a console that can be operated comfortably while standing. Before him is a telephone handset, cathode ray tube screen, typewriter keyboard and an array of buttons with titles such as "start", "author", "title", "subject" and "help". He hits the "start" button, the console lights up and asks him to identify himself. Since Mr. Jones is at his local library, he taps in a short code which distinguishes him from other users of this particular library. (A longer code can identify him uniquely wherever he might be.) The machine ascertains that he is a valid user of the system and asks how it can be of service.

Mr. Jones is seeking a specific volume today. He remembers the author's name as "Licklighter" and that the book is about libraries, so he hits the button labeled "author" and types in the name, then the button labeled "subject" and types in "library". Finally, he taps the "search" button and the machine begins to examine its files. For about 30 seconds the screen is blank; then it flashes: "Your query can not be found. However, authors with the same Soundex code who have written about libraries include:" Names of authors and titles follow. Among them is "Licklider, J.C.R. Libraries of the Future. 65-13831." This is the book Mr. Jones is seeking, so he types in 65-13831 and hits the "locate" button.

This time, the blink of the screen is barely perceptible. It reads: "The copy held in our library has been charged out and is due back on March 3. The nearest available copy can be obtained through Inter-Library Loan in four days." (If he presses the "Inter-Library Loan" button, a request is sent immediately to the lending library and appropriate entries are made in the loan files of each.) Mr. Jones wants the book today. He has forgotten how to query the borrower file, so he picks up the telephone handset. A RULAS aide asks: "How may I assist you?" Mr. Jones explains the problem. The aide (who was automatically linked to the user's console when he picked up the handset) explains the procedure as she strikes the buttons to reveal (on both their screens) that Professor Smith on extension 576 has the book. Mr. Jones' office is next door to Professor Smith, so he thanks the aide, hits a button marked "local telephone system" and the keys 576. Professor Smith answers and agrees to turn the book over to Mr. Jones if he will pick it up. They hang up; Mr. Jones hits the button marked "change" and the change is recorded in circulation's records. He hurries away to pick up the book. The system flashes: "Do you have further queries?" on its screen. Since no one responds by hitting the "yes" button within 15 seconds, the console shuts itself off and awaits the next user.

To illustrate a few of RULAS' features, this example has been a little more complex than a typical interaction. Yet, it by no means exhausts the system's capabilities. The sit-down consoles are there, for example, for those who may spend days using the machine to organize an exhaustive bibliography in a particular field; upon completion, this bibliography could be made a RULAS file available to all its users. Other consoles can be used by librarians to acquire new volumes, control circulation or alter the files to make them more responsive to changing needs. In fact, RULAS is designed to perform any of the actions depicted in Figure 3 (page 8).

Furthermore, anything that can be programmed on a computer can be done on RULAS. For RULAS is a general purpose computer which has the capability to change as needs and understanding change. Its justification is to do existing tasks better but its long-range significance is to make possible things which cannot be done at all with existing capabilities.

Description of a Region

To ascertain the needs of a typical region to establish design parameters, we have constructed a detailed statistical picture of New England's College and University Libraries (Appendix 3). The choice does not imply any preference for that area; it was selected as a convenient, well-defined region with a variety of libraries.

The New England area spends $22 million annually in 152 college and university libraries which serve a quarter million students. The 27 million volumes in these collections grow by 1.2 million additions per year. Taken as a whole, the magnitude of the region's library resources makes the area an obvious candidate for automation. Yet, only a few of the largest libraries have even an experimental mechanization program. To understand why, look at the extremes. Northeastern University has 22,000 students; Oblate College, Maine, has 22. Harvard has more than seven million volumes; Bliss College, Maine, has 2,000. Harvard spends $5,250,000 annually to operate its library; Bliss spends $2,300. Project ISE seeks to help "most" of the nation's colleges and universities; suppose we eliminate the extreme cases by defining "most" to mean 90%. The range between the 5th and 95th percentile then becomes:

	Percentile	
	5th	95th
Students served	73	7,900
Volumes in collection	4,000	520,000
Volumes added per year	300	25,000
Annual expenditures	$7,300	$668,000

In other words, the range of each of these key parameters spans approximately two orders of magnitude! (It happens, incidentally, that the median values, which are used as the design center, are near the geometric mean of the 5th and 95th percentiles.) Our study provides a system which will meet the needs of libraries within this range.

Scope

Although RULAS will replace the functions of a card catalog, the long-range goal is more than simply automating known uses. The plan also brings to everyone in the library a new kind of resource, one embodying programmable processing capability along with storage. The system's uses will be as diverse as its users; as their interests change, RULAS must also change. Thus, it is a general-purpose bibliographic tool that, although quickly operational, will never be complete.

This paper is not a system design; that task will be accomplished in conjunction with RULAS' potential users during the first year of actual development. It is a preliminary study of economic feasibility. The emphasis, therefore, is on costs rather than services. Although the general scope of these services is implied, details are left to the imagination of the reader.

Cost estimates are all intended to err on the generous side. No new equipment development or price reductions are assumed. The actual cost of RULAS, therefore, could be significantly less than our estimates.

Project MARC

The Library of Congress is currently supplying, on an operational basis, machine readable versions of the LC catalog cards for English language monographs (about 50% of the output of the Card Division) on magnetic tape at $600 per year.[18/] This MARC II service is a well-designed, tested and practical system which is intended to encompass all of the titles cataloged by the Library of Congress. It is a sound cornerstone for an automated catalog system. RULAS, therefore, will exploit this basic capability to provide the continuing input to the system.

Converting the Backlog

The full benefits of a unified library automation system will be available only when all titles are available through the computer. Yet, when considering the costs of converting the accumulation of centuries to machine readable form, too many people instinctively recoil. Let us, therefore, face the problem squarely. In so doing, we shall be extremely conservative. We shall assume no technological breakthroughs, although optical character readers adequate to handle a significant fraction of the printed Library of Congress cards should be available in time to reduce costs substantially. We shall further assume that the sole justification for conversion is its value to users in higher education, although the value to others will be at least as great. We shall even assume that the entire cost must be depreciated in ten years, although the benefits clearly will continue for many decades. Yet, despite this obvious over-conservatism, we shall discover that the conversion cost per user is only a few cents!

The cost of converting a title to machine readable form has been variously estimated. The highest is the experience of $1.574 during the Pilot Phase of Project MARC.[18/] Naturally, with experience and economics of scale, costs should be reduced substantially. An IBM study for the Council of

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18/ Paul R. Reimers, Coordinator of Information Systems, Library of Congress. Personal Communication. 15 October 1968.

Library Resources;[19] for example, used sampling techniques to estimate $0.3531 per title, with equipment used on a two-shift basis. Ralph Shoffner, of the University of California at Berkeley, estimated that it will "cost no more than 20 cents a title to get clean and edited machine-readable information."[20] Shoffner's estimate is buttressed by actual experience at Johns Hopkins University, [21] where the conversion of call number, author and title (about one-third of the total information) has been carried out for six cents. The geometric mean of $0.56 per title is less than a factor of three from the two extremes of $1.57 and $0.20 and is about twice the IBM estimates; it should be adequately conservative.

Parenthetically, serious consideration should be given to the practicability of using counterpart funds to do the bulk of the conversion overseas.

The National Union Catalog at the Library of Congress is the largest in the world. At present, "the total number of unique titles in the NUC is 12.2 million." [18] (This is almost twice the size of the largest university collection.[22] At $0.56 per card, 12.2 million cards can be converted into machine-readable form for $6,850,000. Depreciation over a ten year period gives an annual cost of $685,000. With 6.9 million students and faculty in higher education[23] the annual pro rata share is 10 cents. In other words, the yearly cost per person is about the price of an airmail stamp. Potential benefits are obviously many times greater. Furthermore, this is an extremely conservative estimate; we expect conversion to cost much less, to

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18/ See footnote, page 14.

19/ Council on Library Resources, Inc. Report of a Pilot Project for Converting the Pre-1952 National Union Catalog to a Machine Readable Record. Federal Systems Division, IBM Corp., Rockville, Md. 1 July 1965.

20/ Henriette D. Avram and Barbara Evas Markuson (editors). Proceedings of the Third Conference on Machine-Readable Catalog Copy. Library of Congress, Washington, D.C. 1966.

21/ Johns Hopkins University, Milton S. Eisenhower Library. Progress Report on an Operations Research and System Engineering Study of a University Library. Baltimore, Md. June 1965.

22/ T. Samore and D.C. Holladay (editors). Library Statistics of Colleges and Universities, 1963-64. U.S. Dept. of H.E.W., Washington, D.C. 1965.

23/ Kenneth A. Simon and W. Vance Grant. Digest of Educational Statistics, 1967 Edition. U.S. Dept. of H.E.W., Washington, D.C. 1967.

benefit many who are outside of the nation's colleges and universities and to retain its value for longer than a decade.

Finally, it is equally evident that the task of conversion must be done once on a national basis and made available to all. The cost is too high for any single library or even for existing or anticipated consortia. In the absence of a national effort, however, a number of groups can be expected to undertake portions of the task which are of a particular local interest. These uncoordinated efforts, which will still fail to meet national needs, can easily aggregate to a far higher cost than that of doing the job properly in the first place.

Inventory

The existence of a NUC title entry does not, of course, tell where the volume may be found. RULAS is designed to locate the most readily available copy of any requested work; to do the job, the system needs an inventory of each member library.

An individual library is best qualified to conduct its own inventory; no funds, therefore, are programmed for this task. We can, however, estimate the approximate cost, assuming that full advantage is taken of the assistance RULAS can provide. Some of the cost of a complete inventory will, obviously, depend upon existing records. Since the status of such information in each library is unknown, we shall limit our attention to the inescapable minimum of recording the inventory. Although the necessary files probably exist in most cases, some allowance for obtaining the basic data should be added.

The LC card number is the shortest unique identifier of a particular title; for most libraries, it will be the most efficient way to record the inventory. A card number is about one percent of the total number of characters on an LC card. Allowing two percent of the already ample \$0.56 estimated for converting an entire entry gives about one cent per volume. A median library, with 31,000 volumes, would spend a minimum of \$310 to record the one-time inventory. Needless to say, the cost would be many times higher except for the existence of the NUC entries in machine-readable form.

Storage Requirements

The National Union Catalog currently contains 12.2 million titles and increased 0.2 million in the past year; an average title entry is 457 characters.[18/] Allowing for some growth and rounding, about 6.5 billion characters (5.2×10^{10} bits) would contain this information in uncompressed form. At $\$10^{-4}$ per bit, the storage capacity can be provided for $5.2 million, or about $1.04 million per year. Prorating the cost over a region containing about 10% of the college and university population gives an average share of about $4,500 per institution or $1.51 per user. Considering the substantial benefits of having a catalog of the nation's library resources immediately available and the potential savings at the individual libraries, the cost is not unreasonable. It is, however, large enough to warrant serious consideration of practicable means for reduction.

These data in the catalog are highly redundant. In principle, data could be stored in about one bit per character with the proper coding[24/] instead of the eight bits per character we have allowed. In practice, however, such efficient codes are too clumsy to use. But, relatively simple techniques such as brevity codes (Appendix 4) for author, publisher and place of publication, plus a monographic Huffman code[25/] for title could reduce total storage requirements by as much as 25%. Since 25% of $5.2 million is $1.3 million, such techniques are well worth considering; they could reduce the annual per user cost of storage to $1.14 ($3,400 per institution).

Naturally, users would seldom be aware of the existence of any coding techniques. Since all requests must come through the computer, it will make all the necessary transformations automatically. While these conversions require additional computing capability, the added cost is trivial relative to the saving in storage.

[18/] See footnote, page 14.

[24/] Claude E. Shannon and Warren Weaver. The Mathematical Theory of Communication. University of Illinois Press, Urbana, Illinois. 1949.

[25/] D. Huffman. Proceedings of I.R.E., Vol. 40, No. __ (________ 1952). pages 1098-1101.

Storage Structure

Merely storing 12.2 million titles does not, of course, assure quick and economical access to them. When RULAS is being designed, substantial effort will be required to select a storage structure that is tailored to needs of this unique system. Since, however, the details of the structure are highly dependent upon the characteristics of the equipment actually being used, it is premature to define such details in this paper. For the present, it is adequate to recognize that the problem is solvable within the approximate levels of performance and resources that are being assumed.

Backup Storage

Failure of the main file hardware must not destroy the catalog. A duplicate copy (or copies) should be kept for recovery from catastrophic faults. Obviously, this backup can be slow and sequentially accessed but it must be cheap; magnetic tape is the clear choice. Tape cost for 6.5 billion characters is approximately $10,000. A pair of tape drives with controllers will cost about $70,000. With the customary five year depreciation, the annual cost is $16,000.

Microfilm Edition

Although RULAS is designed to provide full-time availability, some librarians might want a completely independent, manual system for emergency or other uses. The cheapest way to provide the capability is on microfilm. Magnetic tape to microfilm converters are commercially available; most libraries already have a microfilm reader. In effect, the center could periodically produce a "book catalog" in microfilm form; prints of this catalog could then be supplied to anyone who needs them.

Microfilm can accommodate about 2,000 frames (20,000 entries) per 100 foot reel. If each title averages four entries, the catalog will contain about 50 million items on 2,500 reels (50 cubic feet). Generating a master reel on a magnetic tape to microfilm converter requires about 30 minutes; the entire catalog can be produced in a year of single shift operation, at a cost of $80,000. Copies made on movie printers would cost about $15,000 each. If ten libraries share expenses, the per copy cost becomes $21,500. Although this price is substantial, it is considerably cheaper than any alternative scheme for duplicating a current version of the National Union Catalog. The economy depends, of course, on the availability of the data in machine readable form and the opportunity to use RULAS equipment at very low cost on an "as time is available" basis.

User Interface

High output bandwidth and quiet operation requirements dictate the use of CRT terminal for the individual libraries. Several commercially available devices offer all the necessary features at a median price of $4,800.[26/] Because of the number needed (1000 per region, 10,000 nationwide), however, it would be possible to design and repackage a terminal which is optimized for library use at about the same price. We allot $5,000 per device ($1,000 per year with five year depreciation), which averages $4,350 per institution or $1.45 per user annually.

It should be recognized that this estimate is based on an elaborate, powerful, and relatively expensive terminal. In fact, its cost represents almost half of the prorated annual costs of the entire system. In some applications, such versatility is necessary; however, a substantially less powerful (and expensive) device can undoubtedly fill many needs. The development of cheaper user interfaces is, therefore, a prime candidate for further reduction in user costs.

Communications

Incoming Wide Area Telephone Service (WATS) would permit any of the approximately 1,000 terminals in the region to access the center conveniently. At $6,000 per line,[27/] 50 incoming lines with unlimited service cost $300,000 annually. This expenditure averages $1,300 per institution or $0.44 per user. Naturally, an optimized system would be cheaper; this estimate, however, does provide an adequate first approximation to communications costs.

26/ D.J. Theis and L.C. Hobbs. "Low-Cost Remote CRT Terminals." Datamation, Volume 14, Number 6 (June 1968). pages 22-29.

27/ David Laycock, Chesapeake and Potomac Telephone Company Business Representative. Personal Communication. 15 November 1968.

Central Processors

The central processor requirements for RULAS are surprisingly small. Although about 1,000 user stations are expected to have access to the system, the density of queries should be quite low and the average computing time per query extremely small. Reasonable assumptions are 5% of the stations in use at any one time, with each active user generating one query per minute, giving an average of only 50 queries per minute. By programming to take advantage of overlapping i/o times, even the smallest computer (costing about $\$10^4$) can handle this load. An extra processor for reliability will add another $\$10^4$. Adding a generous $\$8 \times 10^4$ for ancillary storage (excluding the main file) brings the total to $\$10^5$ ($20,000 per year with five year depreciation).

Building and Replicating the System

An initial, operational version of RULAS can be constructed and validated in five years with an expenditure of 100 man-years of professional effort. Concurrently, the NUC backlog conversion could be completed and integrated into the system. The total development cost is estimated to be less than $12 million or about 25¢ per college and university user in the United States.

While the first system is undergoing initial operational use and refinement, the bulk of the development staff would turn its attention to installing subsequent systems at six month intervals. By the end of the decade, every college and university library in the country could have access to RULAS. In fact, the capability could probably be made available to every library for about the same total cost. Appendix 5 outlines a practical schedule and budget to meet these objectives.

Pricing the Services

Once RULAS becomes operational, its cost should be borne by the individual libraries. Since prorating by institution would be inequitable and charging for individual queries will require too much accounting overhead, an annual charge per terminal is an attractive arrangement. With approximately 1,000 i/o devices in a region, charges could be made quite equitable. Assuming that the one-time, nationwide costs of development and backlog conversion

SUMMARY OF COSTS

	Total (in millions)	Average Annual Cost (in dollars) per Institution	Terminal	User
Nationally Shared Items*				
System development	$ 5.0	$ 435	$ 100	$0.15
NUC backlog conversion	6.85	300	69	0.10
TOTALS	$11.85	$ 735	$ 169	$0.25
Regionally Shared Items**				
User terminals	$ 5.0	$4350	$1000	$1.45
Mass storage	3.9	3400	780	1.14
Communications	1.5	1300	300	0.44
Central processors	0.1	87	20	0.03
Backup storage	0.07	70	16	0.02
MARC tapes	0.0006	3	1	0.001
TOTALS	$10.6	$9210	$2117	$3.08

* Prorated over 2,300 institutions, 10,000 terminals and 6,885,000 students and faculty in higher education.

** Each region is assumed to have one-tenth of the national totals.

are paid for by the federal government, the annual equipment, operations and maintenance costs per terminal would total about $2,200. A single terminal, therefore, would be within the financial means of virtually the smallest library; yet, even the largest can be given a quality of service it cannot afford to provide through unilateral action. Everyone benefits; every library should be eager to participate.

Conclusion

A feasibility study for supplying access to the nation's library resources to everyone in higher education suggests that a national, unified library automation system can be constructed within the next decade. The service provided will exploit cost sharing to be substantially better than any system that individual libraries might provide for themselves and will be within the economic reach of virtually the smallest libraries. Upon completion, the system can be completely self-sustaining with per library service charges as small as $2,200 annually.

APPENDIX 1

SELECTED LIBRARIES WITH INTERESTING COMPUTER APPLICATIONS

Institution: University of California (Berkeley)
Application: Planning; Center for Information Services; File Effectiveness; Handbook on DP for Libraries; Facsimile Transmissions (LDX between Berkeley and Davis); Library Goals (to 1980); Processing Center System; Analysis of Book-form Catalog; University Union Catalog; Mechanization of Clerical Processes; Intercampus Circulation; Education for Librarians.
Contact: Ralph M. Shoffner, Head Operations Task Force, Institute of Library Research

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Institution: University of California (Irvine)
Application: CALM-Computer Assisted Library Mechanization; Acquisition Procedures
Contact: Herbert K. Ahn, Head Library Systems Analysis Office

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Institution: University of California (San Diego)
Application: Development of a system for computer control of serial records (2,000-10,000)
Contact:

Institution: University of California (Los Angeles)
Application: Technical Processing of In-process Files; Off-line Control System for Books in Process; Automatic Production of Catalog Cards and Book Catalogs; Development of an Automated Circulation Control System in the University Research Library; UCLA Biomedical Library Automated Serials; Automation of the Central Serial Department Fiscal Files; Development of a Computer Produced Union List of Serials (titles and locations) for the UCLA Library System; Center for Information Services; MEDLARS Search Station; Brain Information Service-an automated documentation center specifically concerned with the basic neurological sciences; Clearinghouse for Junior College Information Documentation and Retrieval at center for Junior College information; Information Retrieval System for Maps; Automation of Administrative Files
Contact: Anthony F. Hall, Director of Library Systems Development

Institution: Stanford University
Application: On-line Book Purchasing System; Book Cataloging; Hoover Library-testing computer searched information retrieval to provide complete indexing of all documents in Archives by coordination of any number of search terms; The library will take the "total systems" approach in preference to interim sub-systems.
Contact: David C. Weber, Assistant Director, Stanford University Library

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Institution: Yale University
Application: Computerized catalog card production; Acquisition Procedures
Contact:

Institution: Georgia Institute of Technology
Application: Preparing a system for the production of a computer-printed serials holdings list. The file will also contain additional data which will make it possible to print a number of special purpose listings. Planning and programming is in progress for a system which will automatically produce on a 2201 programatic Flexowriter complete sets of catalog cards from a single typing of the unit-card data. The same keying information will provide for computer in put to provide book catalogs.
Contact:

Institution: Argonne National Laboratory (University of Chicago)
Application: Most of applications are in area of technical processing. Journal renewal on tape on the 1401 handles renewals, bid lists, current status reports of all subscriptions, renewal notices, accounting reports, and lists of library and individual subscribers. Union list published annually now on tape. Report-operation is almost completely computerized. Circulation for one branch is handled on computers. Book catalog system designed outside the library. Will discontinue production of catalog card. Work on SDI system on 360. Going to computerize acquisitions on 360.
Contact: Hillis L. Griffin, Information Systems Libraries, Library Services Department, 9700 South Class Avenue, Argonne, Illinois 60439

Institution: University of Chicago

Application: Development of a computer based bibliographica data system. The system will combine into a computer accessible permanent record all elements of information about each book or other bibliographical items added to the library. Initially this stored bibliographic information will be used to generate card catalogs, circulation cards, current acquisition lists and assist in other operations. Implementation of on-line circulation system.

Contact:

Institution: Harvard University

Application: Semi-automated ordering system for the Harvard College Library; Harvard participates in MARC project. Wants to use system designed by LOC for cataloging; Widner has a punched card circulation system which was installed in '63, no changes planned; Baker library at Business School has been working on a computerized serial check in system. Functioning systems are production and publication of lists of current journals by title and subject (Washington University Medical School and Loyola have similar systems); Widner is converting its manuscript sheet shelf lists to machine readable form for official use; Widner is revising and updating its classification schedules and converting them to machine readable form; Countway Medical Library is one of MEDLARS regional centers.

Contact: Richard Gennaro, Assistant University Librarian

Institution: Massachusetts Institute of Technology

Application: Project INTREX; Assembling an experimental augmented catalog and text access system. Available in 1968 to selected users. Intends to catalog 10,000 documents (engineering and science). Storage and retrieval programming; Study of attendance and use of the Science Library at M.I.T. Serial holdings converted to IBM punched cards; Technical Information Project-TIP; Evaluation of search strategies. Project MAC; Proposal for development of machine language compatible method for international scientific and technical communications.

Contact: Carl Overhage, Director, Lincoln Laboratory

Institution: State University of New York
Application: Developing plans for centralized acquisition and processing services for its 58 libraries. It is planning to develop a central computer with terminals in the 58 libraries and 3 regional centers.
Contact: M. Vasiliou, Project Director of Regional Computing Center; Carl Cox, Library Systems Coordinator

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Institution: Columbia University
Application: Cataloging-experimenting with MARC tapes; Are implementing a computer supported interim circulation system for central circulation system which is function oriented; Are creating a union list of serials for science, engineering and medical titles; Acquisition-cataloging project to develop general systems which may have applicability to other institutions and to coordinate development and design work with other large research libraries engaged in similar work; A computer based reserve system has been designed-systems focus on records creation and records management aspects of reserve processing
Contact: Richard Logsdon, Director of Libraries

Institution: Ohio College, Columbus, Ohio
Application: Ohio College Library Center - purpose of Center is "to establish, maintain and operate a computerized, regional library center to serve the academic libraries of Ohio (both state and private) and designed so as to become a part of any national electronic network for bibliographical communication".
Contact: Frederick G. Kilgour, Director, Ohio College Library Center

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Institution: Texas A&M
Application: Use IBM 357 chargeout system for books; Serials acquisition processed on IBM 1401; Have IBM 7094; Working on automated serials system which perfoms three major tasks (1) records arrivals and flagging delinquent arrivals, keeps track of all serial holdings to date in collection, (2) orders and renews subscriptions and records payments for each, (3) provides the information requested for more efficient control and analysis of operation, will also produce listings; Automated circulation system
Contact: Bruce Stewart

Institution: Rice University
Application: Circulation Control
Contact: Mr. Ruecking, Head of Circulation Department, Fondren Library

ACTIVITY	INSTITUTIONS
Acquisition and Ordering	University of California at Irvine Claremont College Yale University Stanford University Argonne National Laboratory Harvard University State University of New York Columbia University Texas A&M (serials) University of Michigan
Administrative Files	University of California (Los Angeles)
Bibliographic Processing	University of Chicago
Book-form Catalog	University of California (Berkeley) University of California (Los Angeles) Stanford University Georgia Institute of Technology Argonne National Laboratory (outside design - headache) Southern Illinois University
Card Cataloging	Claremont College University of California (Berkeley) University of California (Los Angeles) Yale University Georgia Institute of Technology Argonne National Laboratory (with acquisitions) University of Chicago Columbia University University of Toronto (with acquisitions)
Circulation Control	University of California (Los Angeles) Argonne National Laboratory (one branch) Chicago University Harvard University Columbia University Texas A&M Rice University

ACTIVITY	INSTITUTIONS
Classification	Los Angeles State College Harvard University (Widner)
Clerical Processes	University of California (Berkeley) Argonne National Laboratory
Documentation Center	University of California (Los Angeles) (for brain information service and Junior Colleges)
File Effectiveness	University of California (Berkeley) University of California (Los Angeles)
Fiscal Procedures	University of California (Los Angeles) (of Serials Department) Argonne National Laboratory
Information Retrieval	University of California (Los Angeles)(for maps) Stanford University (Hoover Library) M.I.T. (INTREX)
Information Services (Center for)	University of California (Berkeley) University of California (Los Angeles) (collect data from retrieval systems and make readily accessible)
Integrated Systems	Penn State University University of Illinois University of Missouri Stanford University Columbia University
Intercampus Circulation	University of California (Berkeley)
Joint Efforts	State University of New York (Binghamton and Buffalo), Cornell University, Syracuse, and University of Rochester have formed Five Associated University Libraries Regional Computing Center at University of Buffalo

ACTIVITY	INSTITUTIONS
Librarian Education	University of California (Berkeley)
MARC (Loc) cataloging	Harvard University
	Columbia University
	University of California (Los Angeles)
	University of Chicago
	University of Florida
	Georgia Institute of Technology
	Indiana University
	University of Missouri
	Rice University
	University of Toronto
	Yale University
MEDLARS	University of California (Los Angeles)
	Harvard University
	Colorado University
	Alabama University
	Michigan University
Processing Center System	University of California (Berkeley)
	University of California (Los Angeles)
	Florida Atlantic University
Serials	University of California (San Diego)
	University of California (Los Angeles) (Biomedical Library)
	Georgia Institute of Technology
	Harvard University (business school)
	M.I.T.
	Columbia University
	Texas A&M
	Purdue University
SDI (Selective Dissemination of Information)	Argonne National Laboratory
	Florida Atlantic University
Transmission	University of California (Berkeley)
	Davis University (LDX)
	M.I.T. (INTREX)
Union Catalog	University of California (Berkeley)
	University of California (Los Angeles) (of serials)
	Argonne National Laboratory
	State University of New York

APPENDIX 2

Expected Number of Distinct Titles in a Union Catalog

To derive the expected number of distinct titles in a union catalog as a function of the total number of titles in all of the participating libraries,

let:

i = $1, 2, \ldots, j$, designate particular libraries,

j = the number of libraries in the union catalog,

k = $1, 2, \ldots, m$, designate particular titles,

m = the total number of titles available to libraries,

n_i = the number of distinct titles in the i th library,

N = the number of titles in the combined collection (i.e., $N = \sum_{i=1}^{j} n_i$)

p = the number of distinct titles in the union catalog,

q_{ik} = 0 when the k th title does not occur in the i th library,
= 1 when it does occur,

q_k = 0 when the k th title does not occur in the union catalog
= 1 when it does occur.

assume:

1. each library formed its collection independently of every other library, and
2. the number of titles in any single library is much smaller than the total number of titles available to all libraries.

Derivation:

$$E(p) = E\left(\sum_{k=1}^{m} q_k\right)$$

$$= \sum_{k=1}^{m} E\ (q_k)$$

$$= m\ \Pr\ (q_k = 1)$$

$$\Pr\ (q_k = 1) = 1 - \prod_{i=1}^{j} (1 - \Pr(q_{ik} = 1))$$

$$\Pr\ (q_{ik} = 1) = \binom{1}{1} \binom{m-1}{n_i-1} \Big/ \binom{m}{n_i}$$

$$= \frac{(m - 1)}{(n_i - 1) \quad (m - n_i)} \cdot \frac{n_i \quad (m - n_i)}{m}$$

$$= n_i / m$$

$$E\ (p) = m\ (1 - \prod_{i=1}^{j} (1 - (n_i / m)))$$

When $n_i \ll m$ (i.e., assumption 2), $n_i / m \cong 0$, $1 - n_i / m \cong e^{-n_i / m}$, therefore,

$$E\ (p) \cong m\ (1 - \prod_{i=1}^{j} e^{-n_i / m})$$

$$\cong m\ (1 - e^{-\frac{1}{m} \sum_{i=1}^{j} n_i})$$

$$\cong m\ (1 - e^{-N/m})$$

Observations:

1. When the size of the unified collection is small relative to the number of titles available, $1-e^{-N/m} \cong N/m$ so $E(p) \cong N$. Heuristically, the number of distinct titles in a small union catalog is approximately equal to the total number of titles in the participating libraries.

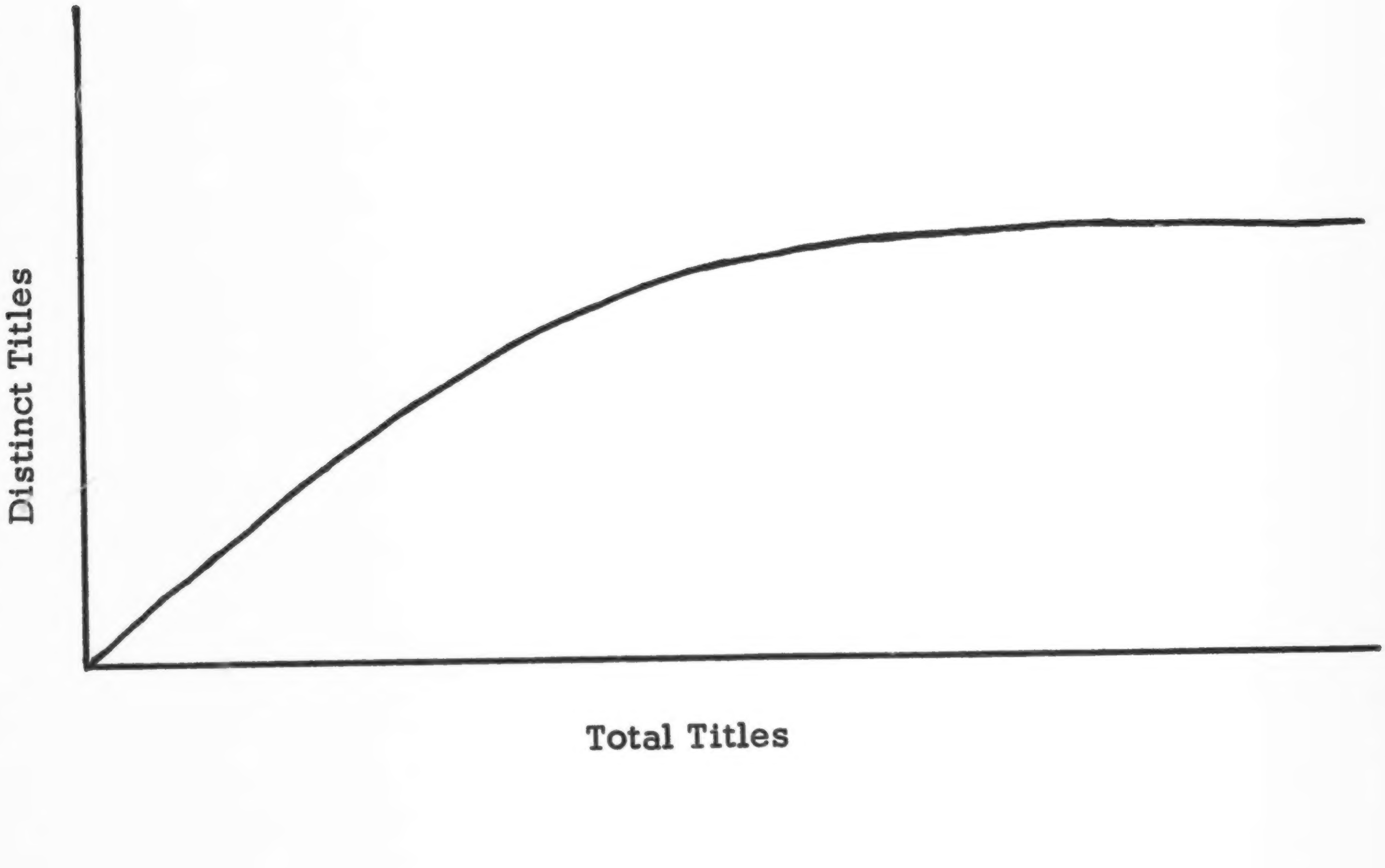
2. When the size of the unified collection is large relative to the number of titles available, $e^{-N/m} \cong 0$ so $E(p) \cong m$. Heuristically, the number of titles in a large union catalog is approximately equal to the number of titles available.

3. The expression $E(p)$ is continuous with positive slope $\leqq 1$. An accompanying figure shows its approximate shape.

Acknowledgement:

The derivation in this Appendix was provided by Dr. Morton Kupperman, Professorial Lecturer in Statistics at The George Washington University.

A Sketch of the Expected Number of Distinct Titles in a Union Catalog as a Function of the Total Number of Titles in All of the Participating Libraries



APPENDIX 3

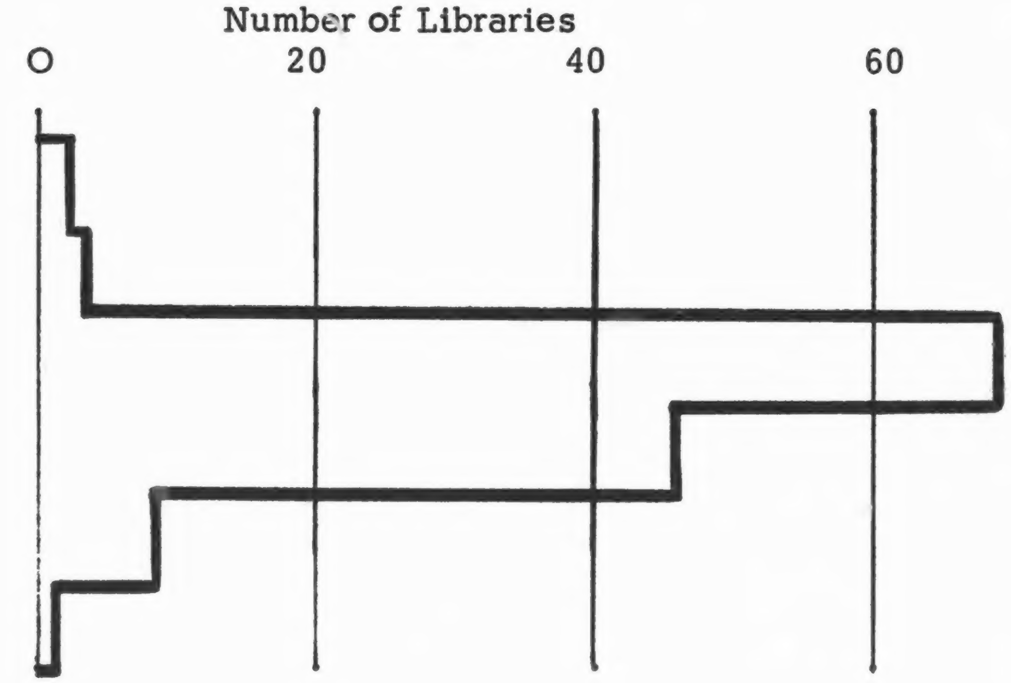
A Statistical Description of New England College and University Libraries

Source: T. Samore and D.C. Holladay (editors). Library Statistics of Colleges and Universities, 1963-64. U.S. Dept. of H.E.W., Washington, D.C. 1965.

Percentage of Institutional Expenditures Allotted to the Library

New England College and University Libraries

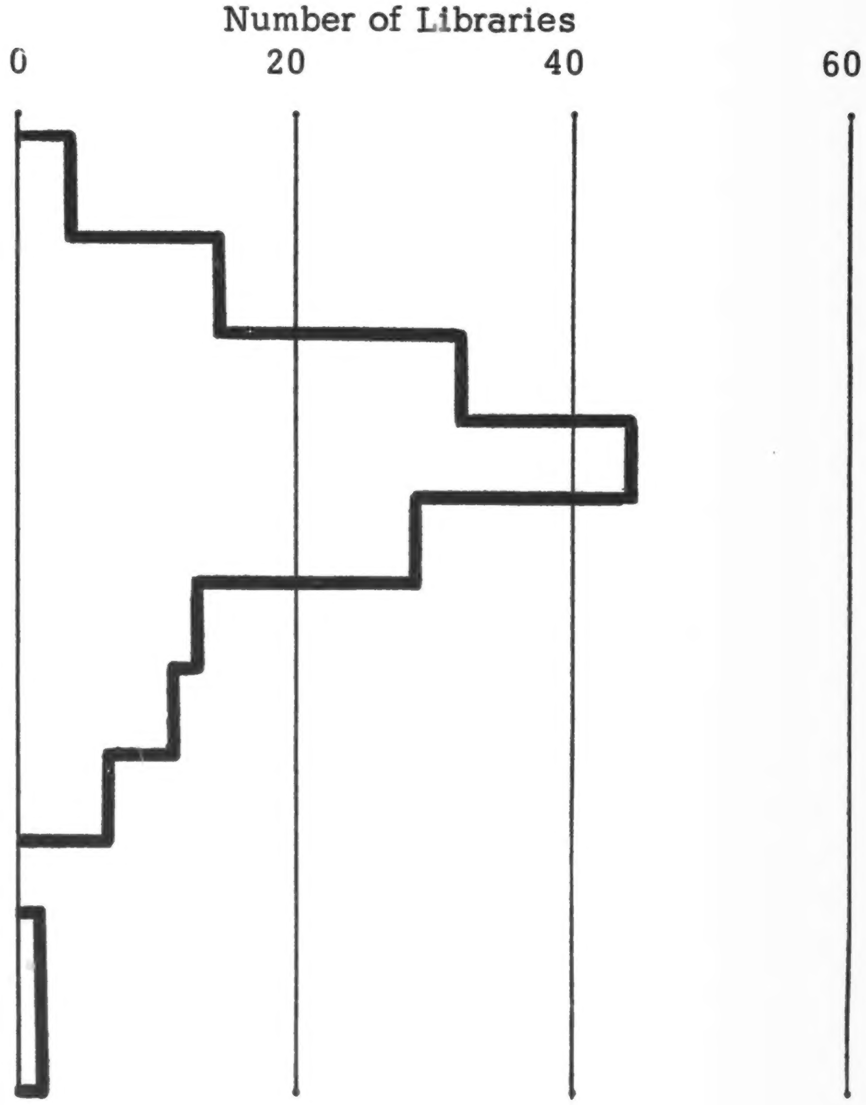
Percentage of Total Expenditures	
0.5-1	2
1-2	3
2-5	70
5-10	45
10-20	7
20-50	1



Total Annual Operating Expenditures

New England College and University Libraries

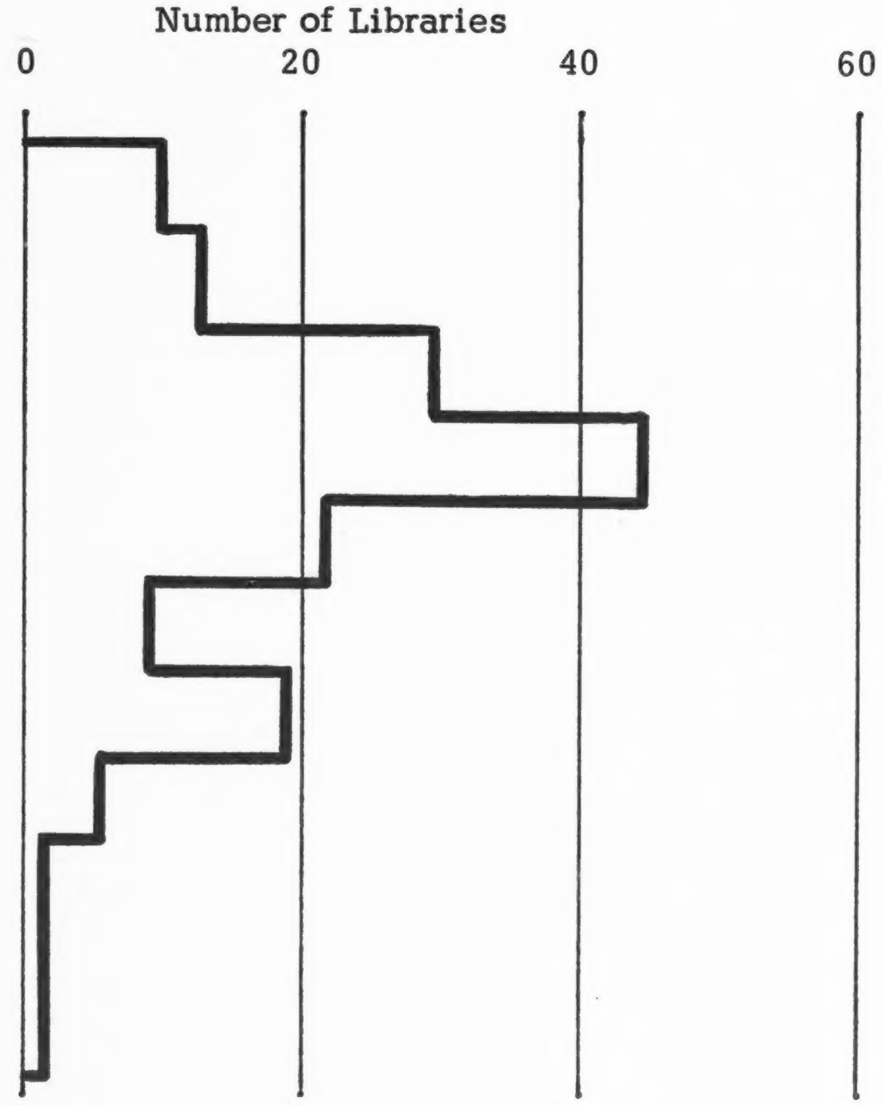
Thousands of Dollars	
2-5	4
5-10	14
10-20	31
20-50	44
50-100	27
100-200	13
200-500	12
500-1000	6
1000-2000	0
2000-5000	1
5000-10,000	1



Number of Volumes in the Collection

New England College and University Libraries

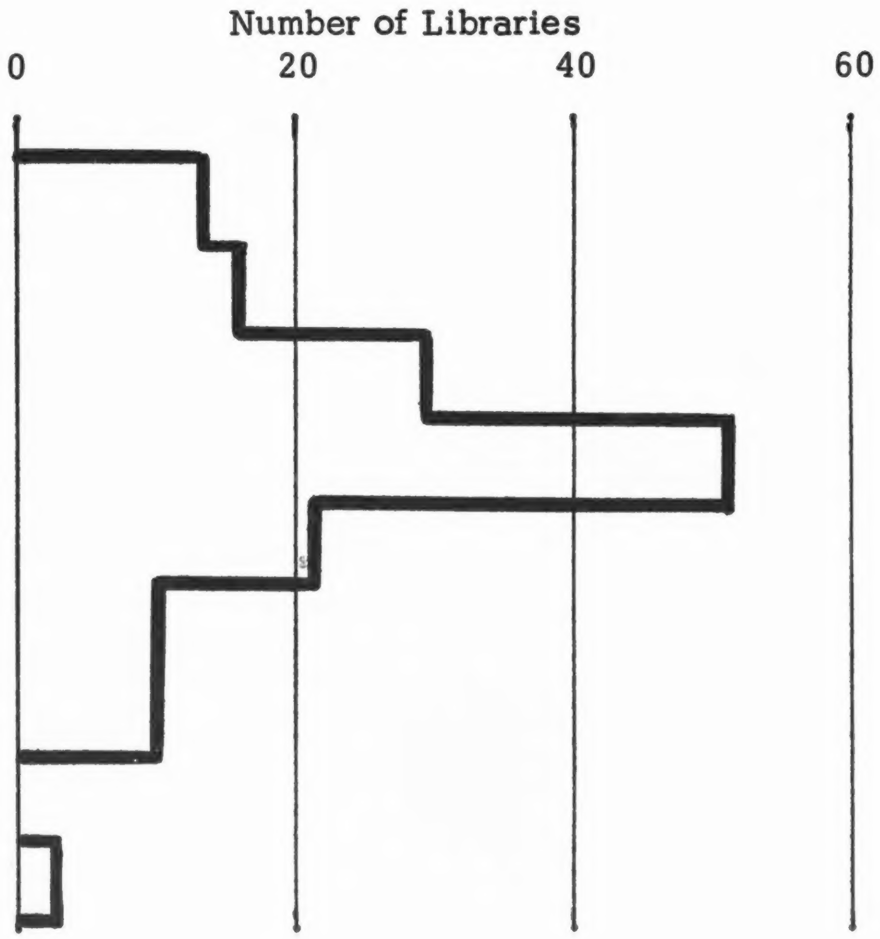
Thousands of Volumes	
2-5	10
5-10	12
10-20	29
20-50	44
50-100	21
100-200	9
200-500	19
500-1000	5
1000-2000	1
2000-5000	1
5000-10,000	1



Number of Volumes Added During Year

New England College and University Libraries

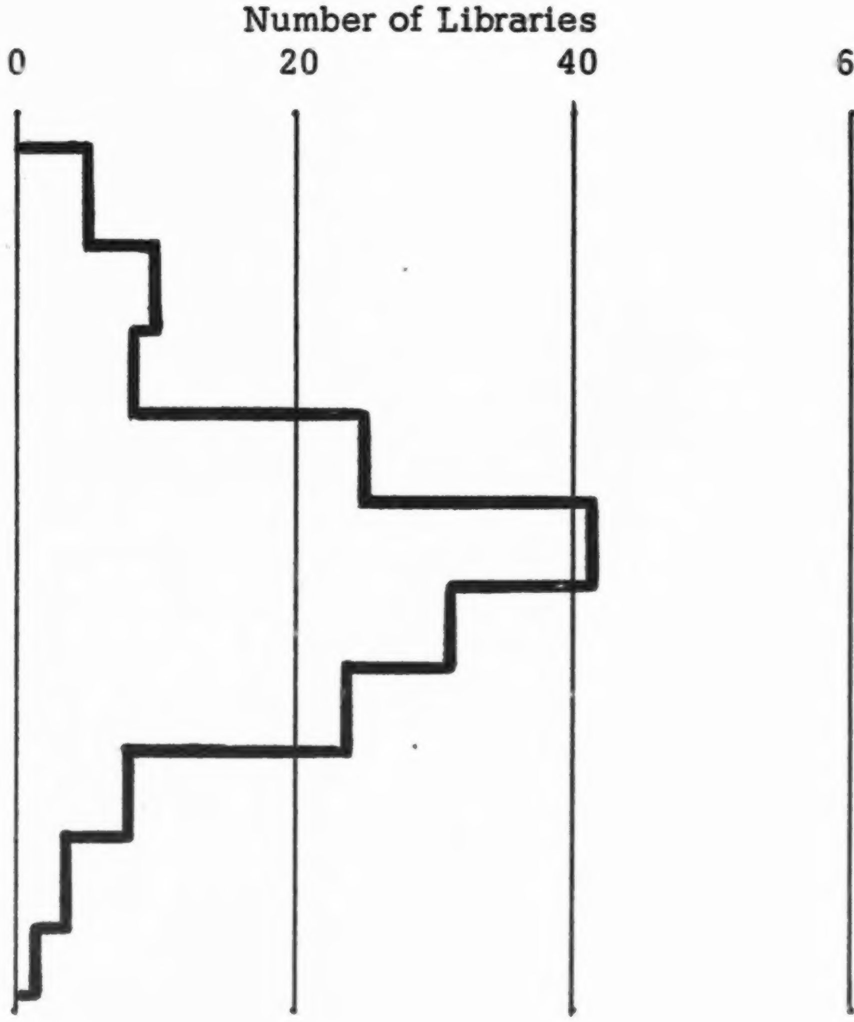
Thousands of Volumes	
to-0.5	13
0.5-1	15
1-2	29
2-5	52
5-10	21
10-20	10
20-50	10
50-100	0
100 - up	2



Number of Students Served

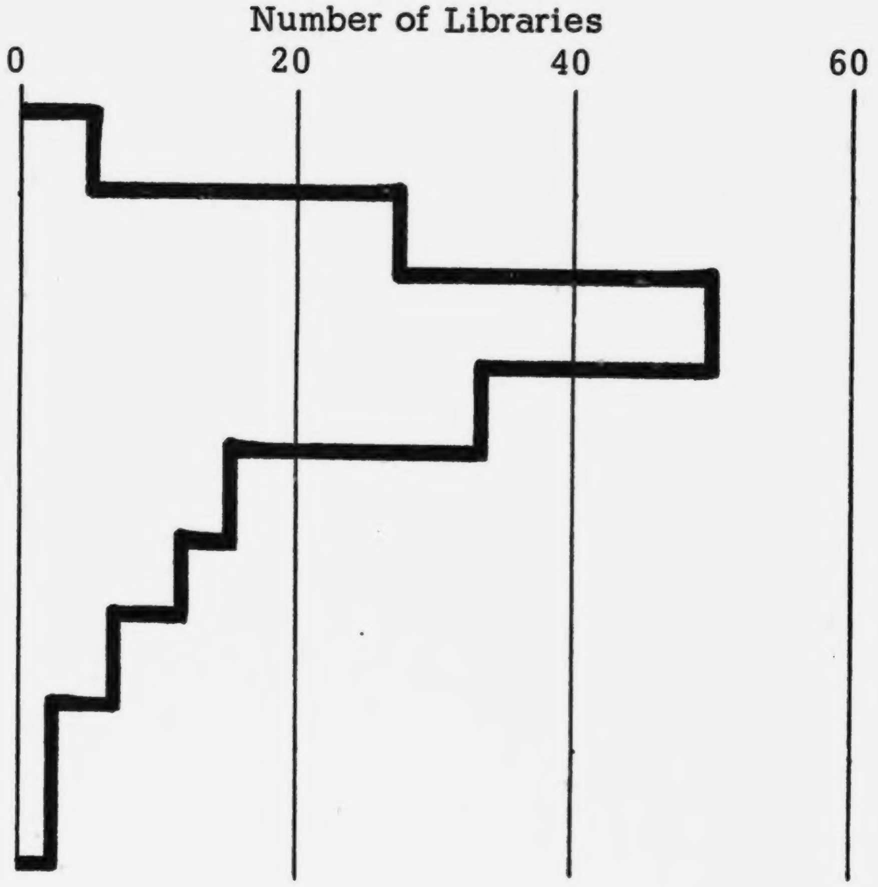
New England College and University Libraries

Hundreds of Students	
0.2-0.5	4
0.5-1	9
1-2	8
2-5	24
5-10	41
10-20	31
20-50	23
50-100	8
100-200	3
200-500	1



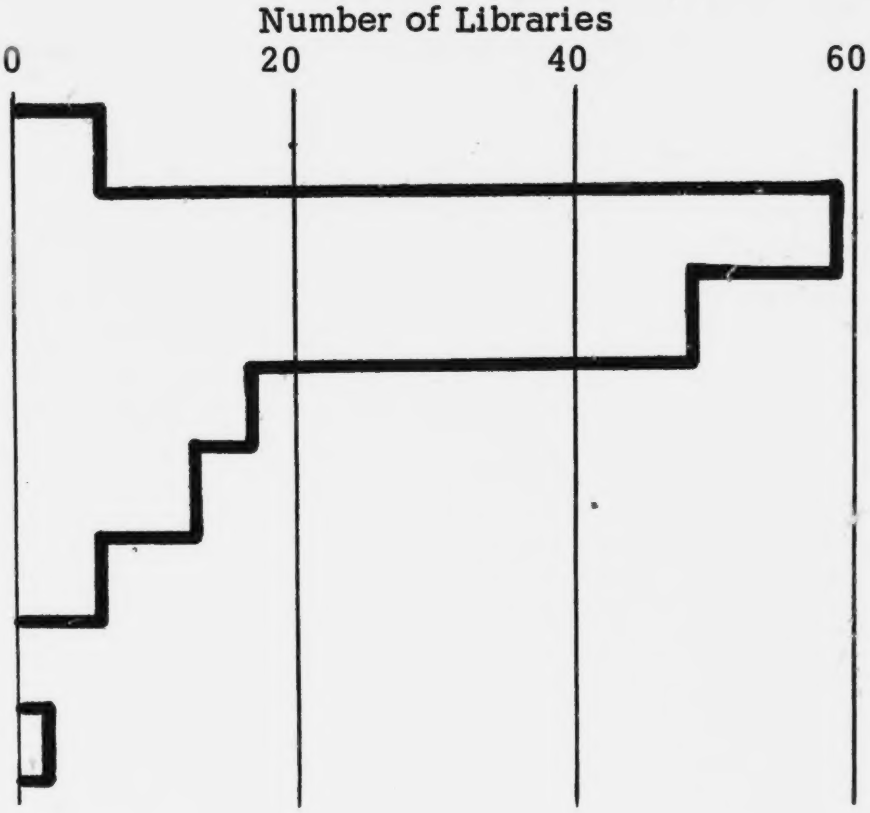
Total Personnel in Full-Time Equivalents
New England College and University Libraries

Personnel	
less than 1	5
1-2	27
2-5	50
5-10	34
10-20	15
20-50	11
50-100	6
100-200	2
200-500	2



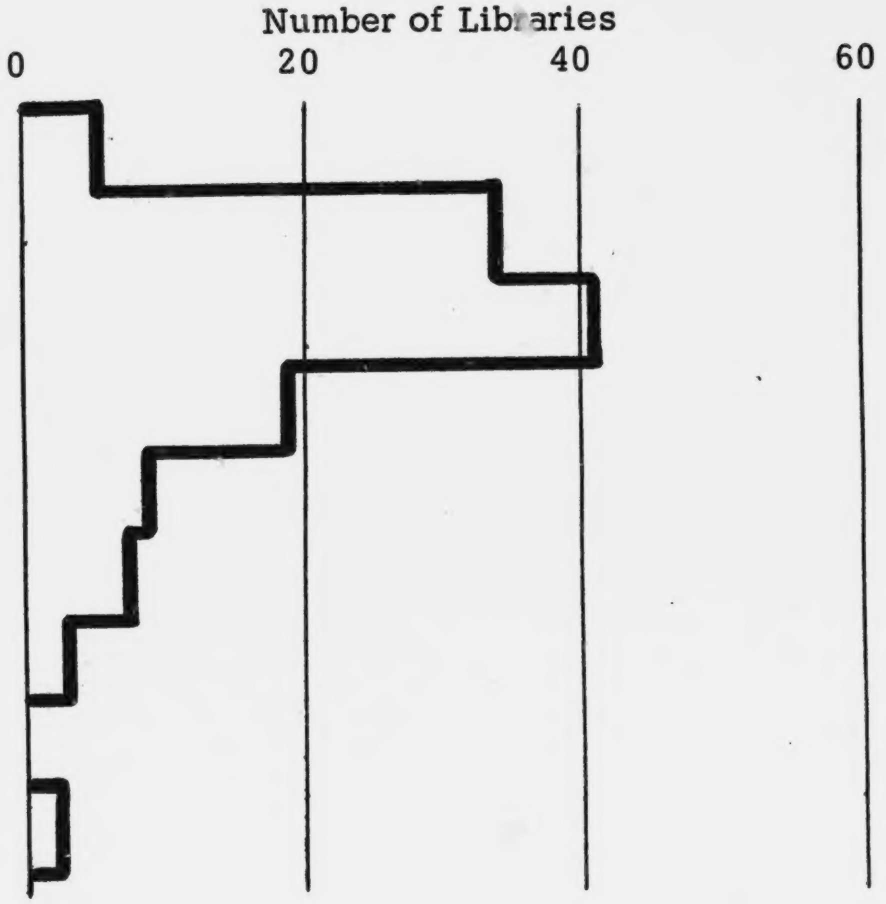
Professional Personnel in Full-Time Equivalents
New England College and University Libraries

Professionals	
less than 1	6
1-2	59
2-5	48
5-10	17
10-20	13
20-50	6
50-100	0
100-200	2



Non-Professional Personnel in Full-Time Equivalents
New England College and University Libraries

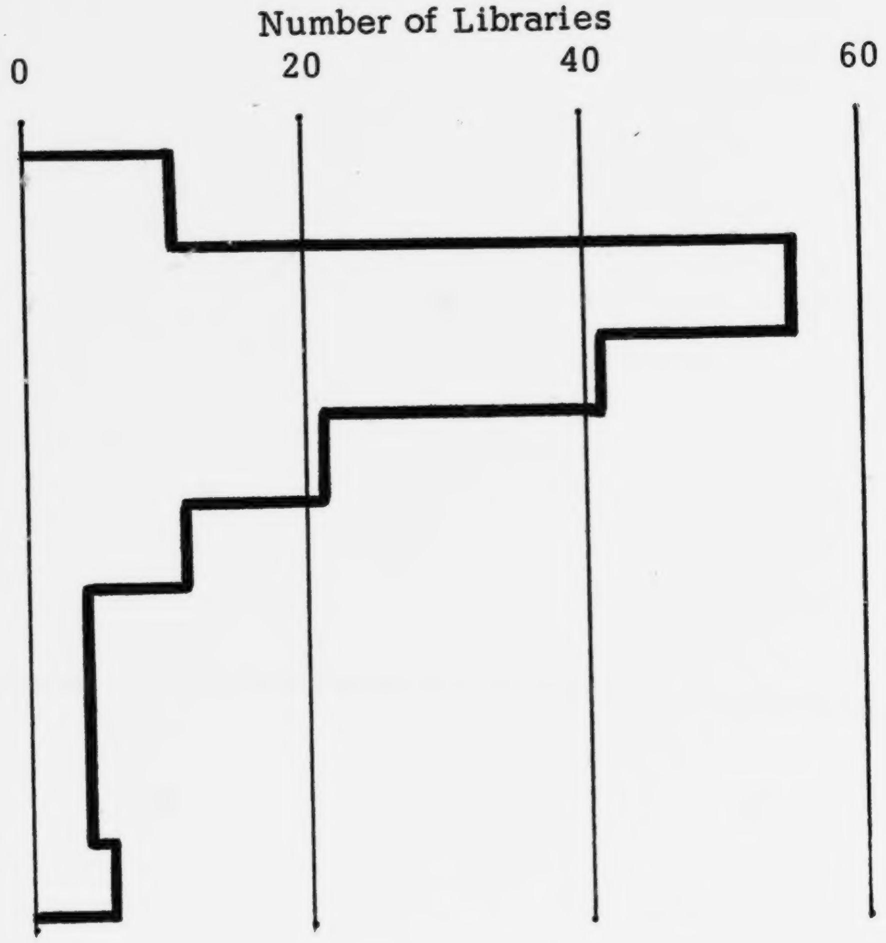
Personnel	
less than 1	6
1-2	34
2-5	41
5-10	19
10-20	9
20-50	8
50-100	3
100-200	0
200-500	2



Annual Expenditures per Volume

New England College and University Libraries

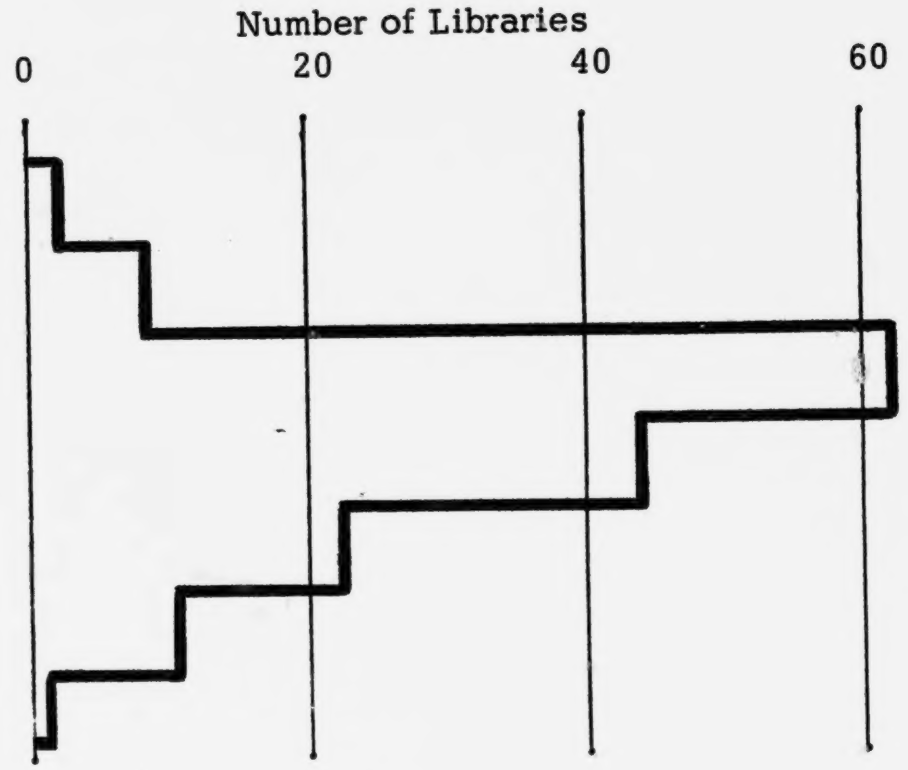
Cents per Volume	
0-50	10
50-100	55
100-150	41
150-200	21
200-250	11
250-300	3
300-350	3
350-400	3
400-up	4



Annual Expenditures per Full-Time Equivalent Student

New England College and University Libraries

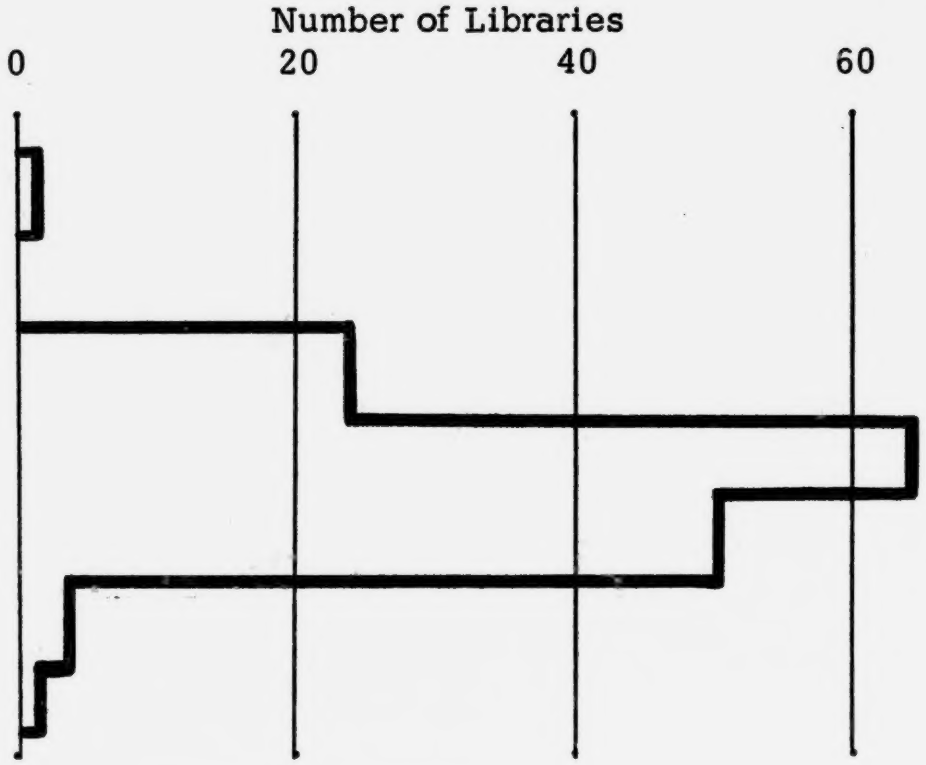
Dollars per Student	
5-10	2
10-20	8
30-50	62
50-100	45
100-200	22
200-500	10
500-1000	1



Annual Expenditures per Full-Time Equivalent Faculty Member

New England College and University Libraries

Dollars per Faculty Member	
50-100	1
100-200	0
200-500	23
500-1000	64
1000-2000	50
2000-5000	3
5000-10,000	1



Annual Expenditures per Volume as a Function of Number of Volumes

New England College and University Libraries

Thousands of Volumes	Cents per Volume								
	0 50	50 100	100 150	150 200	200 250	250 300	300 350	350 400	400 450
2-5			2	2	1	1	1	1	2
5-10		3	2	3	2	1	1		
10-20		8	9	4	3			2	2
20-50	3	14	16	8	2	1			
50-100	3	9	6	1	2				
100-200	1	4	2	1	1				
200-500	3	10	3	2			1		
500-1000		4	1						
1000-2000		1							
2000-5000		1							
5000-10,000		1							

Libraries: 0 □ 1-2 ▨ 3-up ▨

Number of Volumes Added During Year as a Function of Number of Volumes

New England College and University Libraries

Thousands of Volumes	Thousands of Volumes: to 0.5	0.5 1	1 2	2 5	5 10	10 20	20 50	50 100	100 up
2-5	4	4	1	1					
5-10	3	3	4	2					
10-20	4	6	10	8	1				
20-50	2	2	13	24	3				
50-100			1	11	6	1			
100-200				5	5		1		
200-500				1	6	8	4		
500-1000						1	4		
1000-2000							1		
2000-5000									1
5000-10,000									1

Libraries 0 ☐ 1-2 ▨ 3-up ■

Number of Students Served as a Function of Number of Volumes

New England College and University Libraries

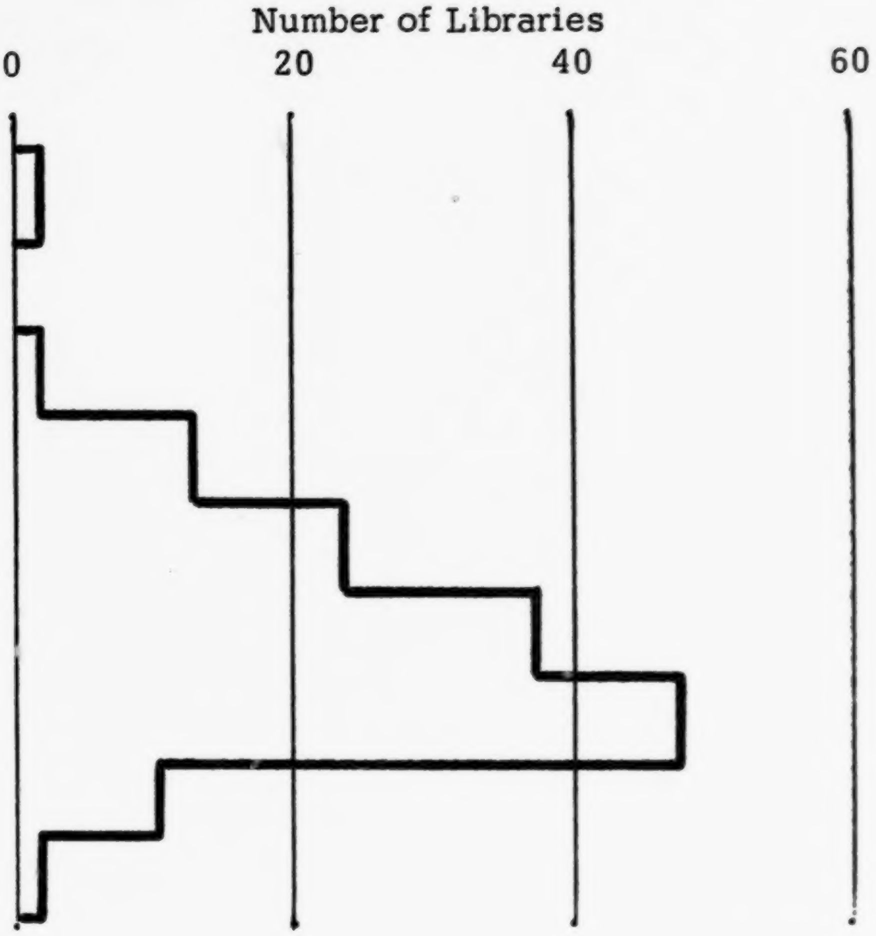
Thousands of Volumes	Hundreds of Students								
	0.2 0.5	0.5 1	1 2	2 5	5 10	10 20	20 50	50 100	100 up
2-5		1	2	3	4				
5-10	2	2		4	4				
10-20	2	4	3	7	8	2	3		
20-50		2	1	9	17	10	5		
50-100			2	1	4	6	8		
100-200				2	1	3	1	1	1
200-500					1	9	4	4	1
500-1000						1	1	2	1
1000-2000							1		
2000-5000								1	
5000-10,000									1

Libraries: 0 ☐ 1-2 ▨ 3-up ■

Percentage of Library Expenditures Allotted to Salaries and Wages

New England College and University Libraries

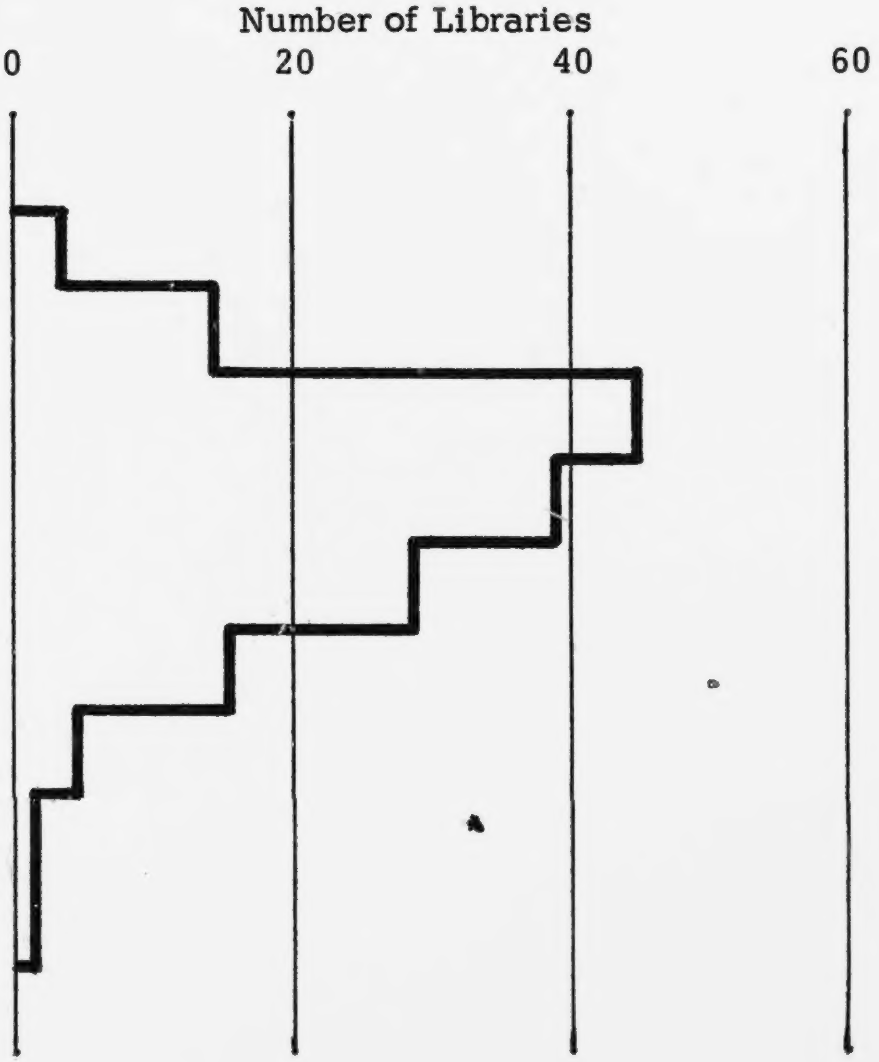
Percent	
0-10	1
10-20	0
20-30	1
30-40	12
40-50	23
50-60	38
60-70	47
70-80	10
90-100	1



Percentage of Library Expenditures Allotted to Books and Materials

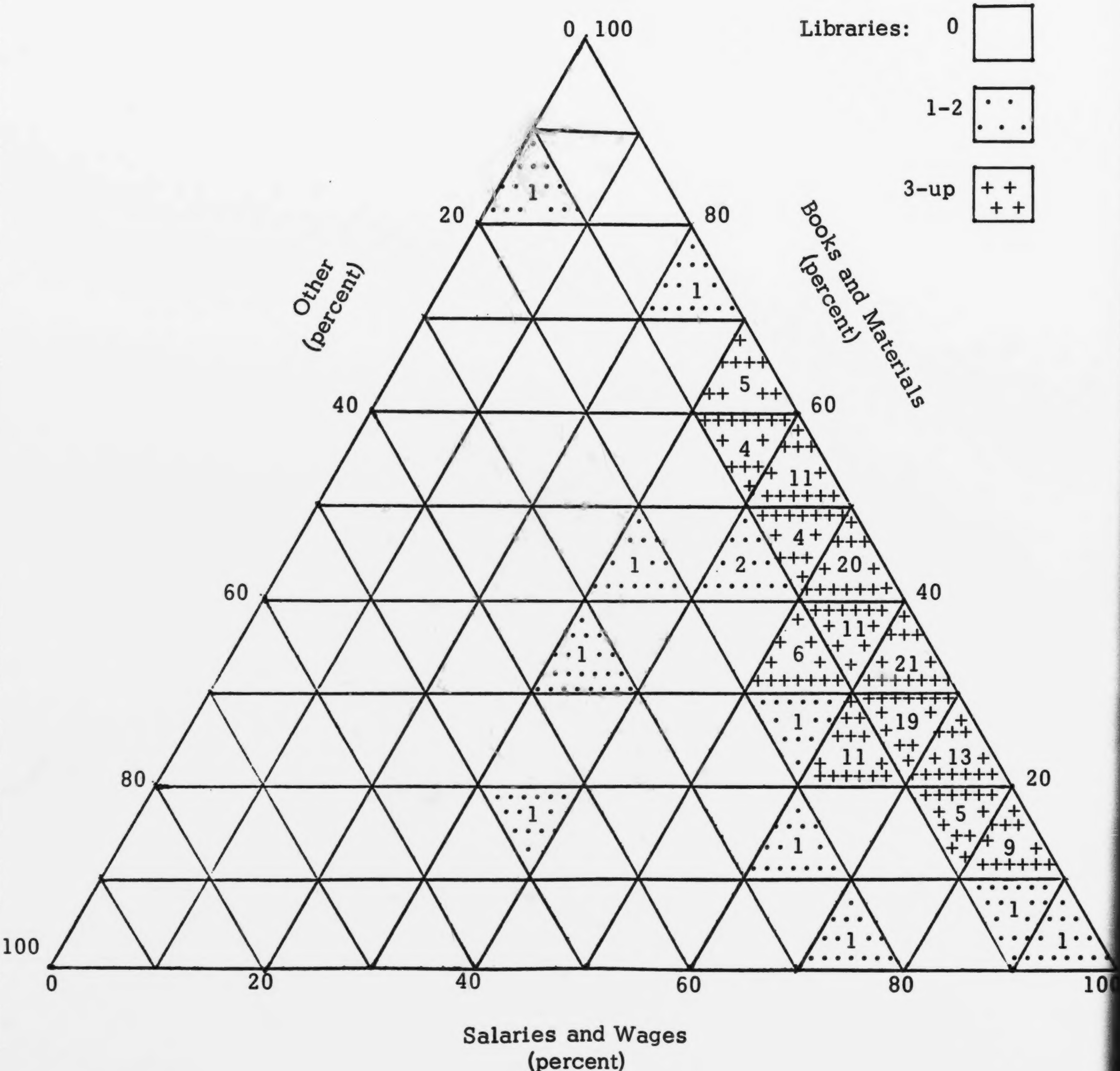
New England College and University Libraries

Percent	
0-10	3
10-20	16
20-30	44
30-40	39
40-50	27
50-60	15
60-70	5
70-80	1
80-90	1
90-100	0



Allocation of Total Operating Expenditures

New England College and University Libraries



Brief Characterization of Small, Medium and Large Libraries

New England College and University Libraries

	Percentile 5	 50	 95
	(small)	(medium)	(large)
Students served	73	818	7,896
Volumes in collection	4,000	31,064	517,279
Volumes added per year	305	2,500	24,938
Annual expenditures	$7,285	$40,578	$668,004

Total and Arithmetic Means

New England College and University Libraries

	Total	Arithmetic Mean
Students served	287,209	1,890
Volumes in collection	26,882,597	176,900
Volumes added per year	1,217,212	8,000
Annual expenditures	$22,287,431	$146,500

Selected Management Data
On New England College and University Libraries
By State and Institution

State and institution	Control and type of institution (see headnote)	Enrollment data				Data on library collection					Personnel in full-time equivalents	
		Total number of students (including terminal-occupational)'	Percent of total (approx.)			Number of volumes at end of year	Number of volumes added during year	Number of volumes withdrawn during year	Number of physical units of microform at end of year	Number of periodicals being received at end of year	Professional	Nonprofessional
			Full-time undergraduates (including first professional)	Part-time undergraduates	Graduate (including second professional							
CONNECTICUT												
ALBERTUS MAGNUS COLLEGE	2- LA	494	100			46,200	2,200		569	370	1.0	1.0
ANNHURST COLLEGE	2- LA	259	86	14		21,500	800	125	1,267	233	2.0	1.3
BRIDGEPORT ENGR INSTITUTE	2-TEC	690	15	85		5,200	300	100		175	.2	.2
CENTRAL CONN STATE COL	1-TEA	4,946	54	32	14	89,410	9,387	173	3,600	450	7.0	2.0
CONNECTICUT COLLEGE	2- LA	1,489	90	8	2	202,741	6,847	272	30,816	888	5.0	11.0
DANBURY STATE COLLEGE	1-TEA	1,610	59	24	17	60,000	3,742	28	10,079	[illegible]32	4.5	
FAIRFIELD UNIVERSITY	2- LA	2,094	61	1	38	63,950	6,057	134	2,196	[illegible]53	3.0	5.0
HARTFORD SEM FOUNDATION	2-THE	207	42		58	178,772	3,640	1	325	986	4.0	5.0
HARTFORD ST TECH INST	1- TI	886	36	64		3,300	935	20		62	1.0	
HOLY APOSTLES SEMINARY	2-THE	113	100			16,135	2,388	217		108	1.0	3.0
MITCHELL COLLEGE	2- JC	1,216	41	59		19,060	2,500	250	20	78	2.0	1.0
MT SACRED HEART COLLEGE	2- JC	45	98	2		7,000	500			60	1.0	1.0
NEW HAVEN COLLEGE	2-OTH	2,193	36	64		14,710	3,507	690		180	2.3	1.0
NORWALK COMMUNITY COL	1- JC	551	47	53		8,000	2,500			125	.3	1.0
QUINNIPIAC COLLEGE	2- LA	1,632	54	46		22,647	3,699	652		286	2.0	2.5
ST BASILS COLLEGE	2- LA	35	100			10,270	236		45	118	1.3	
ST JOSEPH COLLEGE	2- LA	814	61	13	26	48,103	2,269	193	2,071	450	3.0	1.0
ST THOMAS SEMINARY	2- JC	145	98	2		30,696	1,348	35	52	130	1.2	
SEAT OF WISDOM COLLEGE	2- LA	81	40	60		8,739	1,233	5		104	1.0	.2
SOUTHERN CONN STATE COL	1-TEA	4,853	51	23	26	102,599	24,435	70	4,133	478	9.0	2.0
TRINITY COLLEGE	2- LA	1,486	69		31	435,000	6,182	1,484	4,100	996	8.0	8.0
UNIVERSITY OF BRIDGEPORT	2- LA	7,039	50	35	15	102,556	7,005	113	5,125	1,268	5.5	8.3
UNIVERSITY OF CONNECTICUT	1- U	13,633	69	23	8	497,285	46,659	742	213,383	6,086	18.5	34.0
WESLEYAN UNIVERSITY	2- LA	1,203	92	1	7	517,279	17,296	3,431	40,037	1,627	12.7	16.0
WILLIMANTIC STATE COLLEGE	1-TEA	1,114	44	56		34,295	2,359	279	2,386	351	2.0	3.0
YALE UNIVERSITY	2- U	8,297	68		32	4,703,876	146,978	138,321		3,807	130.0	210.0
MAINE												
AROOSTOOK ST TEACHERS COL	1-TEA	308	100			25,177	1,795	293		246	1.0	
BANGOR THEOLOGICAL SEM	2-THE	112	98	2		53,411	1,702	1,321	19	225	1.0	1.0
BATES COLLEGE	2- LA	891	99	1		121,154	3,759	2,143	1,160	593	4.0	3.2
BLISS COLLEGE	2- SP	98	100			2,000	900			16	.1	
BOWDOIN COLLEGE	2- LA	806	99		1	295,859	13,426	129	6,404	1,072	10.0	8.2
COLBY COLLEGE	2- LA	1,264	98	2		209,447	6,640	990	123	711	5.0	5.5
FARMINGTON ST TEACHRS COL	1-TEA	531	99	1		30,622	1,802	250	35	222	2.0	2.0
FT KENT STATE TEACHRS COL	1-TEA	195	81	19		11,199	576			122		1.0
GORHAM STATE TEACHERS COL	1-TEA	1,215	64	36		30,800	3,525			278	3.0	1.8
HUSSON COLLEGE	2-OTH	837	97	3		3,500	600			170	2.0	1.0
NASSON COLLEGE	2- LA	537	97	3		27,008	3,730	5	244	411	1.0	4.0
OBLATE COLLEGE & SEMINARY	2- JC	22	100			8,300	300	100		80	1.0	
ST FRANCIS COLLEGE	2- LA	343	99	1		21,650	3,314	305		190	1.0	5.0
ST JOSEPHS COLLEGE	2- LA	229	75	25		16,520	1,341			202	1.0	
UNIVERSITY OF MAINE	1- U	7,896	63	34	3	347,642	12,864	3,694	4,565	2,000	13.0	12.0
WASHINGTON ST TEACHRS COL	1-TEA	289	100			18,850	3,875	100		114	1.0	1.0

State and institution	Control and type of institution (see headnote)	Enrollment data				Data on library collection					Personnel in full-time equivalents	
		Total number of students (including terminal-occupational)	Percent of total (approx.)			Number of volumes at end of year	Number of volumes added during year	Number of volumes withdrawn during year	Number of physical units of microform at end of year	Number of periodicals being received at end of year	Professional	Nonprofessional
			Full-time undergraduates (including first professional)	Part-time undergraduates	Graduate (including second professional)							
MASSACHUSETTS												
AMERICAN INTERNATL COL	2- LA	3,270	38	62		57,075	3,179	108	6,021	370	3.0	3.5
AMHERST COLLEGE	2- LA	1,082	98	1	1	365,399	10,169	2,585	12,110	1,170	10.3	14.5
ANDOVER NEWTON THEOL SCH	2-THE	303	86		14	88,193	2,860	10	81	335	2.0	4.7
ANNA MARIA COL FOR WOMEN	2- LA	546	84	16		20,552	1,848	31		250	2.0	1.0
ASSUMPTION COLLEGE	2- LA	805	47	27	26	59,784	2,598		785	500	2.0	4.0
ATLANTIC UNION COLLEGE	2- LA	579	90	10		55,141	3,544	50		500	1.5	2.0
BABSON INST OF BUS ADMIN	2-OTH	884	82	1	17	37,959	1,804	347	346	363	2.3	3.6
BECKER JR COLLEGE	2- SP	610	100			4,000	300		61	75	1.0	1.0
BENTLEY COLLEGE ACC & FIN	2-OTH	3,890	35	65		27,511	4,573	53	302	305	4.3	1.0
BERKSHIRE CHRISTIAN COL	2-THE	81	91	9		12,482	613	30	2	158	.4	
BOSTON COLLEGE	2- U	8,901	72	10	18	621,101	24,938	828	43,937	3,284	20.8	39.2
BOSTON UNIVERSITY	2- U	19,628	66	12	22	607,206	36,280	6,674	86,799	4,305	41.5	49.0
BRADFORD JR COLLEGE	2- JC	347	100			29,132	988	347	408	173	2.0	1.5
BRANDEIS UNIVERSITY	2- LA	1,904	73	5	22	276,433	27,834		68,298	2,043	19.0	25.0
CAPE COD COMMUNITY COL	1- JC	512	75	25		6,085	1,254	21	33	100	1.0	
CARDINAL CUSHING COLLEGE	2- LA	241	98	2		16,701	1,716	15		156	1.0	1.0
CLARK UNIVERSITY	2- LA	2,166	43	46	11	243,870	3,902	32	12,132	1,124	4.0	8.5
COL OF THE HOLY CROSS	2- LA	1,826	99		1	213,558	5,948	221	5,176	660	6.0	9.0
COL OF OUR LADY OF ELMS	2- LA	858	70	26	4	25,463	2,064	278	191	236	1.0	4.0
DEAN JR COLLEGE	2- JC	818	100			12,168	2,321			175	2.0	3.5
EASTERN NAZARENE COLLEGE	2- LA	742	88	12		38,043	2,352	147	47	325	1.0	1.6
ELIOT-PEARSON SCHOOL	2-TEA	179	78	11	11	3,000	305	86		36	1.0	
EMERSON COLLEGE	2- LA	771	87	8	5	23,948	1,848	120	27	253	1.6	2.0
EMMANUEL COLLEGE	2- LA	1,187	98	2		55,455	3,585	385		350	5.0	
EPISCOPAL THEOL SCHOOL	2-THE	132	100			58,419	2,318		10	203	1.0	1.0
FISHER JUNIOR COLLEGE	2- JC	396	100			5,000	1,054			68	1.0	.5
FRANKLIN INST OF BOSTON	1- TI	535	89	11		7,000	500	750		100	1.0	2.0
GARLAND JR COLLEGE	2- JC	315	100			5,787	1,132	27		136	1.0	.8
HARVARD UNIVERSITY	2 U	11,957	66		34	7,245,321	241,221	64,589	25,10[illegible]	27,976	163.0	260.0
LASELL JR COLLEGE	2- JC	669	100			17,397	1,720	13	54	186	3.0	
LESLEY COLLEGE	2-TEA	561	83	6	11	29,191	2,572	150		236	3.0	1.0
LOWELL TECHNOLOGICAL INST	1-TEC	3,159	95	2	3	81,760	6,280		275	563	1.0	7.0
MARIST COLLEGE & SEMINARY	2-THE	59	100			23,200	1,200	15		73	1.0	
MASS BAY COMMUNITY COL	1- JC	705	100			4,671	2,500		150	100	1.0	
MASSACHUSETTS COL OF ART	1- FA	502	100			12,481	779	9		112	2.0	1.0
MASS COL OF OPTOMETRY	2-OTH	124	100			3,196	92			36	1.0	
MASS COL OF PHARMACY	2-OTH	587	95		5	20,000	465	27	17	540	2.0	1.0
MASS INST OF TECHNOLOGY	2-TEC	6,925	52		48	896,513	48,506	1,225	66,952	4,127	43.0	76.5
MERRIMACK COLLEGE	2- LA	2,308	67	33		35,423	4,123	88	252	438	3.0	2.5
MOUNT ALVERNIA COLLEGE	2-THE	69	74	26		9,702	2,000	173		89	1.2	.5
MOUNT HOLYOKE COLLEGE	2- LA	1,647	97		3	292,298	7,845	991	1	1,065	9.0	12.5
NEW BEDFORD INST TECH	1-TEC	991	88	12		24,706	1,906	8	5	325	1.0	
NEW ENG CONS OF MUSIC	2- FA	385	74		26	28,830	1,584	363	15	58	1.0	4.0
NEWTON COL SACRED HEART	2- LA	665	100			55,500	4,000	300	25	425	4.0	6.0
NEWTON JR COLLEGE	1- JC	515	82	18		10,989	2,290	126		119	1.0	1.0
NICHOLS COL OF BUS ADM	2-OTH	603	100			13,208	1,122	64	90	170	1.0	2.0
NORTHEASTERN UNIVERSITY	2- U	21,731	39	43	18	130,000	9,620	1,430	14,411	1,620	11.0	18.0
NORTHERN ESSEX CMTY COL	1- JC	393	97	3		5,013	358		4	126	1.0	1.0
PINE MANOR JR COLLEGE	2- JC	321	100			17,053	1,028	650	179	147	2.0	
QUEEN APOSTLES COL & SEM	2-THE	23	100			15,351	436	1,067		117	1.0	1.0
RADCLIFFE COLLEGE	2- LA	1,147	100			138,909	6,118	1,949	98	431	6.0	6.0
REGIONL CMTY COL GREENFLD	1- JC	264	96	4		6,182	830			86	1.0	
REGIS COLLEGE	2- LA	789	99	1		61,500	2,200	197	150	407	3.0	2.0
ST HYACINTH COL & SEM	2- LA	73	100			27,100	437			149	1.0	2.0
ST STEPHENS COLLEGE	2-THE	61	69		31	14,000	2,000	1,000	20	50	1.3	.5
SIMMONS COLLEGE	2- LA	1,782	90	1	9	110,791	6,040	465	374	842	7.0	5.0
SMITH COLLEGE	2- LA	2,434	91	6	3	477,385	11,925	1,414	6,802	1,890	16.0	20.0
SPRINGFIELD COLLEGE	2- LA	1,784	79	13	8	65,695	6,096	142	2,457	439	3.0	6.3
STATE COL AT BOSTON	1-TEA	3,716	51	4	45	31,000	2,076	57	627	330	4.0	2.0
STATE COL AT BRIDGEWATER	1-TEA	2,854	53	11	36	38,483	3,204	231	220	441	5.0	2.0
STATE COL AT FITCHBURG	1-TEA	1,577	63	37		25,045	3,998			322	2.0	3.5
STATE COL AT FRAMINGHAM	1-TEA	1,684	55	45		32,148	2,148	86	120	350	4.0	
STATE COL AT LOWELL	1-TEA	736	100			29,893	4,293	300	335	178	2.0	
STATE COL AT NORTH ADAMS	1-TEA	979	52	15	33	19,778	1,750	6	1,225	241	1.0	
STATE COL AT SALEM	1-TEA	2,606	59	3	38	36,000	5,800			320	4.0	1.0
STATE COL AT WESTFIELD	1-TEA	1,351	52	48		41,000	4,000		650	184	1.0	1.0
STATE COL AT WORCESTER	1-TEA	1,832	62	38		46,049	8,223	273	1,672	522	2.0	2.0
STONEHILL COLLEGE	2- LA	1,032	99	1		39,535	5,563	200		705	6.0	1.7
SUFFOLK UNIVERSITY	2- LA	2,083	74	22	4	60,046	2,626	125	75	285	6.0	
TUFTS UNIVERSITY	2- U	4,715	79	12	9	338,001	13,135	3,699	10,153	3,092	12.0	17.7
UNIV OF MASSACHUSETTS	1- U	8,849	83	2	15	294,672	24,485	1,309	29,918	2,256	18.7	42.5
WELLESLEY COLLEGE	2- LA	1,734	99		1	375,015	10,036	947	10,887	1,528	13.0	17.0
WENTWORTH INSTITUTE	2- JC	2,317	88	12		11,458	6,312	403		275	3.0	
WESTERN NEW ENGLAND COL	2-OTH	1,913	30	63	7	15,671	3,108	866		125	1.0	3.0
WHEATON COLLEGE	2- LA	872	99	1		112,396	8,922	538	843	551	6.5	7.0
WILLIAMS COLLEGE	2- LA	1,233	93	3	4	271,630	7,956	168	2,324	1,200	8.5	7.5
WORCESTER JR COLLEGE	2- JC	2,403	38	62		11,613	732	65		115	1.0	
WORCESTER POLY INSTITUTE	2-TEC	1,433	84		16	55,704	6,204	250	100	435	4.0	4.0

State and institution	Control and type of institution (see headnote)	Enrollment data				Data on library collection					Personnel in full-time equivalents	
		Total number of students (including terminal-occupational)	Percent of total (approx.)			Number of volumes at end of year	Number of volumes added during year	Number of volumes withdrawn during year	Number of physical units of microform at end of year	Number of periodicals being received at end of year	Professional	Nonprofessional
			Full-time undergraduates (including first professional)	Part-time undergraduates	Graduate (including second professional)							
NEW HAMPSHIRE												
COLBY JR COL FOR WOMEN	2-OTH	549	99	1		31,997	1,702	470	902	175	3.0	1.0
DARTMOUTH COLLEGE	2- LA	3,456	95		5	879,398	24,848	3,692		3,043	32.5	62.3
KEENE STATE COLLEGE	1-TEA	1,369	68	31	1	40,430	2,947	286	458	322	3.0	2.0
MOUNT ST MARY COLLEGE	2- LA	289	100			22,666	1,151	47		158	1.0	1.0
NEW ENGLAND COLLEGE	2- LA	557	99	1		25,000	3,433	300		120	1.0	3.0
NOTRE DAME COLLEGE	2- LA	279	61	39		12,660	809	10		90	1.0	
PLYMOUTH STATE COLLEGE	1-TEA	1,197	74	25	1	29,891	2,537		411	300	3.0	1.0
QUEEN OF PEACE MISSN SEM	2-THE	73	100			11,000	300	2,000		92	1.0	4.0
RIVIER COLLEGE	2- LA	669	55	36	9	45,000	3,975	50	20	250	1.0	2.0
ST ANSELMS COLLEGE	2- LA	1,345	90	10		50,947	7,260	150	50	725	3.0	3.0
UNIV OF NEW HAMPSHIRE	1- U	6,394	61	31	8	346,304	26,924	3,403	325	2,446	16.1	20.7
RHODE ISLAND												
BARRINGTON COLLEGE	2-THE	451	92	8		31,064	1,784	39	125	244	1.0	2.0
BROWN UNIVERSITY	2- LA	4,453	79		21	1,077,422	33,391	1,377	106,059	8,869	44.4	62.6
CATHOLIC TEACHERS COLLEGE	2-TEA	236	100			3,415	201	20		10	1.0	
PROVIDENCE COLLEGE	2- LA	2,932	83	17		60,699	2,226		291	280	1.0	6.0
RHODE ISLAND COLLEGE	1-TEA	3,370	51	49		54,243	10,421	200	1,639	430	4.0	8.0
R I SCHOOL OF DESIGN	2- FA	912	98		2	33,767	1,195	332		161	4.0	4.0
ROGER WILLIAMS JR COL	2- JC	540	77	23		2,875	574			36	.7	
SALVE REGINA COLLEGE	2- LA	586	95	5		31,600	2,156	156	239	229	1.0	3.0
SEM OF OUR LADY OF PROV	2- LA	88	100			10,041	1,348		47	75	1.0	2.0
UNIV OF RHODE ISLAND	1- U	8,892	44	47	9	241,478	17,742	327	6,522	1,998	14.0	10.0
VERMONT												
BENNINGTON COLLEGE	2- LA	386	96	4		45,575	2,528	382	1,001	313	2.0	4.5
CASTLETON STATE COLLEGE	1-TEA	576	93	7		16,000	1,654	2,750	61	95	1.0	1.0
JOHNSON STATE COLLEGE	1-TEA	312	98	2		13,500	1,029	56	203	135	1.0	1.0
LYNDON STATE COLLEGE	1-TEA	252	97	3		12,359	1,415	60		82	1.0	1.0
MARLBORO COLLEGE	2- LA	106	99	1		11,000	600	2,000		120	1.0	
MIDDLEBURY COLLEGE	2- LA	1,343	100			149,874	4,876	557	4,030	700	7.0	8.0
NORWICH UNIVERSITY	2- LA	4,268	72	28		72,708	2,312	156		429	3.0	2.5
ST MICHAELS COLLEGE	2- LA	1,181	86	14		55,265	2,982	1,846	666	270	2.0	2.0
UNIV OF VT & ST AGRIC COL	1- U	4,028	92	3	5	294,258	12,911	494	15,000	3,316	25.0	26.0
VERMONT COLLEGE	2-OTH	511	100			12,732	339	319		124	1.0	2.0
VERMONT TECH COLLEGE	1- TI	251	100			4,000	1,000	50		80	1.0	

State and institution	Operating expenditures in dollars					
	Total	Salaries	Wages	Books and other library materials	Binding	Other (exclud-ing capital outlay)
CONNECTICUT						
ALBERTUS MAGNUS COLLEGE	25,192	12,425	900	9,969	1,007	891
ANNHURST COLLEGE	22,496	16,307	336	2,935	350	566
BRIDGEPORT ENGR INSTITUTE	3,750	1,350		2,200		200
CENTRAL CONN STATE COL	188,188	61,400	9,873	111,100	3,090	2,725
CONNECTICUT COLLEGE	139,278	71,017	12,988	44,470	4,085	6,718
DANBURY STATE COLLEGE	72,954	26,900	3,533	39,822	1,003	1,696
FAIRFIELD UNIVERSITY	82,344	34,856	4,370	36,270	2,043	4,805
HARTFORD SEM FOUNDATION	55,434	34,534	3,900	12,500	3,000	1,500
HARTFORD ST TECH INST	13,560	6,200	488	6,562		310
HOLY APOSTLES SEMINARY	18,950	13,020	1,600	3,400		930
MITCHELL COLLEGE	29,250	14,900	2,600	10,250	500	1,000
MT SACRED HEART COLLEGE	11,130	6,000		4,280	150	700
NEW HAVEN COLLEGE	34,284	17,809	966	14,280	429	800
NORWALK COMMUNITY COL	13,750	5,750		6,800	1,200	
QUINNIPIAC COLLEGE	39,366	20,058	1,680	16,184	773	671
ST BASILS COLLEGE	9,561	8,000		1,419	27	115
ST JOSEPH COLLEGE	42,927	24,400	1,442	14,283	1,496	1,306
ST THOMAS SEMINARY	11,389	6,790	200	1,650	259	2,490
SEAT OF WISDOM COLLEGE	7,400	3,900		3,100	300	100
SOUTHERN CONN STATE COL	177,121	66,875	3,375	94,489	3,600	8,782
TRINITY COLLEGE	149,599	85,143	12,172	33,573	6,050	12,661
UNIVERSITY OF BRIDGEPORT	132,111	65,634	8,959	50,979	3,974	2,365
UNIVERSITY OF CONNECTICUT	788,808	243,919	29,964	476,877	22,954	15,094
WESLEYAN UNIVERSITY	268,372	132,935	14,156	98,376	16,030	6,875
WILLIMANTIC STATE COLLEGE	66,233	29,320	1,650	33,963	516	784
YALE UNIVERSITY	2,555,731	1,558,115		997,616		
MAINE						
AROOSTOOK ST TEACHERS COL	19,196	7,592	2,120	6,844		2,640
BANGOR THEOLOGICAL SEM	19,581	9,490	2,798	5,411	849	1,033
BATES COLLEGE	65,153	34,738	4,187	21,586	2,550	2,092
BLISS COLLEGE	2,320	500	550	1,196		74
BOWDOIN COLLEGE	177,340	96,005	10,346	51,041	7,992	11,956
COLBY COLLEGE	87,850	47,300	5,400	23,822	5,178	6,150
FARMINGTON ST TEACHRS COL	25,734	17,228	1,277	5,612	464	1,153
FT KENT STATE TEACHRS COL	8,538	3,816	565	3,664		493
GORHAM STATE TEACHERS COL	47,833	24,709	1,180	21,293	199	452
HUSSON COLLEGE	13,800	9,000	1,600	2,500	500	200
NASSON COLLEGE	48,320	16,781	3,233	23,374	599	4,333
OBLATE COLLEGE & SEMINARY	4,350	3,250		900	100	100
ST FRANCIS COLLEGE	30,800	18,300		10,000	800	1,700
ST JOSEPHS COLLEGE	9,706	5,000	322	4,384		
UNIVERSITY OF MAINE	250,505	126,000	44,000	63,285	6,000	11,220
WASHINGTON ST TEACHRS COL	29,220	8,620	600	20,000		
MASSACHUSETTS						
AMERICAN INTERNATL COL	64,764	33,913	4,258	23,502	1,590	1,501
AMHERST COLLEGE	203,740	111,262	9,442	69,390	4,289	9,357
ANDOVER NEWTON THEOL SCH	46,361	27,554	2,088	12,262	1,081	3,376
ANNA MARIA COL FOR WOMEN	19,313	11,820	700	4,994	436	1,363
ASSUMPTION COLLEGE	20,294			16,127	1,311	2,856
ATLANTIC UNION COLLEGE	39,243	10,783	10,379	12,377	462	5,242
BABSON INST OF BUS ADMIN	44,412	22,755	2,247	16,228	349	2,833
BECKER JR COLLEGE	12,320	6,100	720	5,000	500	
BENTLEY COLLEGE ACC & FIN	63,467	31,211	4,600	25,162	689	1,805

State and institution	Operating expenditures in dollars					
	Total	Salaries	Wages	Books and other library materials	Binding	Other (excluding capital outlay)
CONT MASSACHUSETTS						
BERKSHIRE CHRISTIAN COL	9,731	1,333	2,177	1,523	236	4,462
BOSTON COLLEGE	498,696	267,389	42,942	140,000	17,360	31,005
BOSTON UNIVERSITY	668,004	373,008	93,485	161,688	15,258	24,565
BRADFORD JR COLLEGE	28,893	19,012	3,032	6,124	318	407
BRANDEIS UNIVERSITY	475,104	209,042	51,428	161,409	21,330	31,895
CAPE COD COMMUNITY COL	13,160	4,935	425	7,450		350
CARDINAL CUSHING COLLEGE	16,165	9,000	600	5,888	575	102
CLARK UNIVERSITY	100,399	53,884	8,502	29,099	4,478	4,436
COL OF THE HOLY CROSS	118,473	58,744	18,264	31,757	3,259	6,449
COL OF OUR LADY OF ELMS	29,246	18,624	550	8,298	644	1,130
DEAN JR COLLEGE	42,766	24,065	1,630	14,480	404	2,187
EASTERN NAZARENE COLLEGE	36,217	12,600	5,893	15,532	1,227	965
ELIOT-PEARSON SCHOOL	5,627	3,200	777	1,150		500
EMERSON COLLEGE	33,237	12,405	4,871	12,187	148	3,626
EMMANUEL COLLEGE	50,244	27,579	2,336	17,418	1,165	1,746
EPISCOPAL THEOL SCHOOL	18,243	7,800	1,814	7,581	628	420
FISHER JUNIOR COLLEGE	12,238	6,750	1,901	3,308		279
FRANKLIN INST OF BOSTON	10,750	5,500	1,750	3,250		250
GARLAND JR COLLEGE	17,742	7,750	1,000	7,591	31	1,370
HARVARD UNIVERSITY	5,257,150	2,808,766	314,111	1,061,724	218,033	854,516
LASELL JR COLLEGE	26,458	16,500	1,877	7,502	133	446
LESLEY COLLEGE	35,726	16,800	6,785	10,000	991	1,150
LOWELL TECHNOLOGICAL INST	78,966	40,528		37,638	800	
MARIST COLLEGE & SEMINARY	9,073	6,000		2,301	65	707
MASS BAY COMMUNITY COL	23,700	7,400	800	15,000		500
MASSACHUSETTS COL OF ART	47,050	20,000	50	27,000		
MASS COL OF OPTOMETRY	4,400	3,650		650	100	
MASS COL OF PHARMACY	23,748	16,000	750	5,514	951	533
MASS INST OF TECHNOLOGY	834,511	552,168	37,338	185,671	28,272	31,062
MERRIMACK COLLEGE	50,632	26,968	3,896	16,192	1,092	2,484
MOUNT ALVERNIA COLLEGE	9,900	7,000	900	1,611	181	208
MOUNT HOLYOKE COLLEGE	148,950	95,950	6,000	32,300	4,300	10,400
NEW BEDFORD INST TECH	29,200	7,694	2,535	9,700	1,224	8,047
NEW ENG CONS OF MUSIC	26,917	20,600	2,000	3,545	323	449
NEWTON COL SACRED HEART	60,383	38,667	2,515	13,204	2,269	3,728
NEWTON JR COLLEGE	15,220	10,620	600	3,950	50	
NICHOLS COL OF BUS ADM	15,331	8,839	309	5,894	39	250
NORTHEASTERN UNIVERSITY	260,700	105,565	16,000	127,500	6,000	5,635
NORTHERN ESSEX CMTY COL	14,829	12,129		2,327	20	353
PINE MANOR JR COLLEGE	16,617	11,150	1,491	3,155	211	610
QUEEN APOSTLES COL & SEM	10,056	8,200		1,563		293
RADCLIFFE COLLEGE	111,920	56,652	12,112	27,500	2,500	13,156
REGIONL CMTY COL GREENFLD	9,878	4,935	400	4,500		43
REGIS COLLEGE	44,706	27,615	2,756	11,044	1,573	1,718
ST HYACINTH COL & SEM	16,790	12,000	640	2,743	644	763
ST STEPHENS COLLEGE						
SIMMONS COLLEGE	89,030	48,732	10,541	22,800	3,470	3,487
SMITH COLLEGE	322,164	174,321	22,241	98,430	12,682	14,490
SPRINGFIELD COLLEGE	87,081	41,143	4,013	38,755	1,290	1,880
STATE COL AT BOSTON	44,532	35,352	3,035	6,145		
STATE COL AT BRIDGEWATER	69,058	36,099	7,185	22,834	1,446	1,494
STATE COL AT FITCHBURG	68,747	25,625	7,122	35,000	1,000	
STATE COL AT FRAMINGHAM	38,973	18,162	308	20,024		479
STATE COL AT LOWELL	59,461	17,932	5,450	34,530		1,549
STATE COL AT NORTH ADAMS	47,091	6,781	5,121	34,359		830
STATE COL AT SALEM	82,756	36,170	4,541	40,000	1,083	962
STATE COL AT WESTFIELD	60,051	18,701	900	40,000		450
STATE COL AT WORCESTER	74,430	29,430	5,000	39,500		500
STONEHILL COLLEGE	66,411	30,696	4,053	27,276	1,428	2,958
SUFFOLK UNIVERSITY	52,636	30,235	2,593	16,514	1,750	1,544
TUFTS UNIVERSITY	265,281	136,428	24,112	82,890	12,830	9,021
UNIV OF MASSACHUSETTS	912,753	354,800	61,729	468,094	15,975	12,155
WELLESLEY COLLEGE	275,933	153,178	12,332	58,426	7,430	44,567
WENTWORTH INSTITUTE	56,830	17,100	2,730	35,000		2,000
WESTERN NEW ENGLAND COL	33,299	15,764	1,939	12,327	295	2,974
WHEATON COLLEGE	131,826	74,281	12,593	36,584	4,029	4,339
WILLIAMS COLLEGE	176,009	88,583	4,610	66,028	9,127	7,661
WORCESTER JR COLLEGE	15,066	10,100	560	4,406		
WORCESTER POLY INSTITUTE	98,250	45,100	4,500	40,050	2,500	6,100

State and institution	Operating expenditures in dollars					
	Total	Salaries	Wages	Books and other library materials	Binding	Other (excluding capital outlay)
NEW HAMPSHIRE						
COLBY JR COL FOR WOMEN	35,999	22,432	1,592	9,720	1,400	855
DARTMOUTH COLLEGE	690,203	395,439	31,617	199,103	23,212	40,832
KEENE STATE COLLEGE	48,804	24,619	2,286	18,788	449	2,662
MOUNT ST MARY COLLEGE	16,438	7,100	4,200	3,782	163	1,193
NEW ENGLAND COLLEGE	13,399	12,000	1,399			
NOTRE DAME COLLEGE	6,775	4,500	175	2,000	100	
PLYMOUTH STATE COLLEGE	40,578	17,180	1,830	20,351		1,217
QUEEN OF PEACE MISSN SEM	72,000	24,000		30,000		18,000
RIVIER COLLEGE	25,263	15,000	2,517	7,012	466	268
ST ANSELMS COLLEGE	56,247	17,180	3,800	30,758	3,170	1,339
UNIV OF NEW HAMPSHIRE	378,628	184,125	28,137	124,310	14,546	27,510
RHODE ISLAND						
BARRINGTON COLLEGE	15,389	7,700	1,435	5,578	269	407
BROWN UNIVERSITY	817,166	473,191	59,217	204,106	29,957	50,695
CATHOLIC TEACHERS COLLEGE	6,606	5,400		1,206		
PROVIDENCE COLLEGE	37,398	24,830	2,513	9,165	579	311
RHODE ISLAND COLLEGE	123,627	58,417	4,500	55,810	3,000	1,900
R I SCHOOL OF DESIGN	45,409	29,485	1,415	11,383	671	2,455
ROGER WILLIAMS JR COL	7,285	5,500		1,600	35	150
SALVE REGINA COLLEGE	28,553	17,665	268	8,660	305	1,655
SEM OF OUR LADY OF PROV	15,303	13,153		1,438	294	418
UNIV OF RHODE ISLAND	287,912	103,846	13,141	142,206	13,500	15,219
VERMONT						
BENNINGTON COLLEGE	44,913	24,829	3,572	13,432	1,970	1,110
CASTLETON STATE COLLEGE	21,452	10,244	2,366	8,842		
JOHNSON STATE COLLEGE	18,379	11,142	1,644	604		4,989
LYNDON STATE COLLEGE	14,416	7,821	1,480	4,765		350
MARLBORO COLLEGE	11,800	5,500	2,800	3,000	200	300
MIDDLEBURY COLLEGE	99,667	57,900	5,595	30,111	1,899	4,162
NORWICH UNIVERSITY	49,101	26,530	1,565	14,493	1,800	4,713
ST MICHAELS COLLEGE	41,179	21,000	2,711	14,433	900	2,135
UNIV OF VT & ST AGRIC COL	387,723	201,908	29,295	129,260	16,000	11,260
VERMONT COLLEGE	12,887	8,100	1,520	2,456	540	271
VERMONT TECH COLLEGE	8,180	5,500		2,112	23	545

Percentage of total operating expenditures						
State & Institution	Salaries	Wages	Books and Materials	Binding	Other	Annual Expenditures in cents per volume
CONNECTICUT						
Albertus Magnus Col.	49	4	40	4	3	55
Annhurst Col.	81	2	13	2	2	105
Bridgeport Engr Inst.	36	0	59	0	5	72
Central Conn. St. Col.	33	5	59	2	1	210
Connecticut College	51	9	32	3	5	69
Danbury St. Col.	37	5	55	1	2	122
Fairfield Univ.	42	5	44	2	7	129
Hartford Sem. Found.	62	7	23	5	3	31
Hartford St. Tech. Inst.	46	4	48	0	2	412
Holy Apostles Sem.	69	8	18	0	5	117
Mitchell Col.	51	9	35	2	3	154
Mt. Sacred Heart Col.	53	0	38	1	6	159
New Haven Col.	52	3	42	1	2	236
Norwalk Comm. Col.	42	0	49	9	0	172
Quinnipiac Col.	51	4	41	2	2	175
St. Basils Col.	84	0	15	0	1	93
St. Joseph Col.	57	3	33	4	3	89
St. Thomas Sem.	60	2	14	2	22	37
Seat of Wisdom Col.	53	0	42	4	1	85
Southern Conn. St. Col.	38	2	53	2	5	172
Trinity Col.	57	8	22	4	9	35
Univ. of Bridgeport	50	7	39	3	1	128
Univ. of Conn.	31	4	61	3	1	159
Wesleyan Univ.	50	5	37	6	2	52
Willimantic St. Col.	44	2	51	1	2	193
Yale Univ.	61	0	39	0	0	55
Averages	53	2	43	1	1	69
MAINE						
Aroostook St. Teach. Col.	40	11	35	0	14	76
Bangor The. Sem.	48	14	28	4	6	37
Bates Col.	53	6	33	4	4	54
Bliss Col.	22	24	52	0	2	116
Bowdoin Col.	54	6	29	4	7	60

Percentage of total operating expenditures						
State & Institution	Salaries	Wages	Books and Materials	Binding	Other	Annual Expenditures in cents per volume
MAINE continued						
Colby Col.	54	6	27	6	7	42
Farmington St. Teach Col	67	5	22	2	4	84
Ft. Kent St Teach Col	45	7	43	0	5	76
Gorham St. Teach. Col.	52	2	45	0	1	156
Husson Col.	65	12	18	4	1	394
Nasson Col.	35	7	48	1	9	179
Oblate Col. & Sem.	75	0	21	2	2	52
St. Francis Col.	59	0	32	3	6	142
St. Josephs Col.	51	4	45	0	0	59
Univ. of Maine	50	18	25	2	5	72
Washington St. Teach Col	30	2	68	0	0	155
Averages	52	9	31	3	5	69
MASSACHUSETTS						
American Internatl Col	52	7	36	3	2	113
Amherst Col.	55	5	34	2	4	56
Andover Newton The. Sch	59	5	27	2	7	53
Anna Maria Col for W	61	4	26	2	7	94
Assumption Col.	0	0	80	6	14	34
Atlantic Union Col.	28	27	32	1	12	71
Babson Inst of Bus Admin	51	5	36	1	7	117
Becker Jr Col.	50	6	41	3	0	308
Bentley Col Acc & Fin	49	7	40	1	3	232
Berkshire Christian Col	14	22	16	2	46	85
Boston Col.	54	9	28	3	6	80
Boston Univ.	56	14	24	2	4	110
Bradford Jr. Col.	66	10	21	1	2	99
Brandeis Univ.	44	10	34	4	8	173
Cape Cod Comm. Col.	38	3	56	0	3	217
Cardinal Cushing Col.	56	4	36	4	0	97
Clark University	54	9	29	4	4	41
Col of the Holy Cross	50	15	27	3	5	56
Col of Our Lady of Elms	64	2	28	2	4	115
Dean Jr Col.	56	4	34	1	5	353

Percentage of total operating expenditures

State & Institution	Salaries	Wages	Books and Materials	Binding	Other	Annual Expenditures in cents per volume
MASSACHUSETTS continued						
Eastern Nazarene Col	35	16	43	3	3	95
Eliot-Pearson School	57	14	20	0	9	188
Emerson Col	37	15	37	0	11	139
Emmanuel Col	55	5	35	2	3	91
Episcopal Theol School	43	10	42	3	2	31
Fisher Jr Col	55	15	28	0	2	245
Franklin Inst of Boston	51	16	30	0	3	154
Garland Jr. Col	44	6	43	0	7	306
Harvard Univ	54	6	20	4	16	73
Lasell Jr Col	62	7	28	1	2	152
Lesley Col	47	19	28	3	3	122
Lowell Techological Inst	51	0	48	1	0	97
Marist Col & Sem	65	0	25	2	8	39
Mass Bay Comm Col	31	3	64	0	2	507
Mass Col of Art	42	1	57	0	0	378
Mass Col of Optometry	83	0	15	2	0	138
Mass Col of Pharmacy	68	3	24	4	1	119
Mass Inst of Technology	66	4	23	3	4	93
Merrimack Col	53	8	32	2	5	143
Mount Alvernia Col	71	9	16	2	2	102
Mount Holyoke Col	64	4	22	3	7	51
New Bedford Inst Tech	26	9	33	4	28	118
New Eng Cons of Music	77	7	13	1	2	93
Newton Col Sacred Heart	64	4	22	4	6	109
Newton Jr Col	70	4	26	0	0	138
Nichols Col of Bus Admin	58	2	38	0	2	116
Northeastern Univ	41	6	49	2	2	200
Northern Essex City Col	82	0	16	0	2	296
Pine Manor Jr Col	67	9	19	1	4	97
Queen Apostles Col & Sem	67	9	19	1	4	97
Radcliffe Col	51	11	24	2	12	81
Regional City Col Grenfld	50	4	46	0	0	146
Regis Col	61	6	25	4	4	73
St Hyacinth Col & Sem	71	4	16	4	5	62
St Stephens Col	data not available					
Simmons Col	54	12	26	4	4	80

Percentage of total operating expenditures State & Institution	Salaries	Wages	Books and Materials	Binding	Other	Annual Expenditures in cents per volume
MASSACHUSETTS continued						
Smith Col	54	7	31	4	4	68
Springfield Col	48	5	44	1	2	133
St Col at Boston	79	7	14	0	0	144
St Col at Bridgewater	53	10	33	2	2	180
St Col at Fitchburg	37	10	51	0	2	274
St Col at Framingham	46	1	52	0	1	122
St Col at Lowell	30	9	58	0	3	199
St Col at North Adams	14	11	73	0	2	238
St Col at Salem	44	5	49	1	1	230
St Col at Westfield	31	1	67	0	1	146
St Col at Worcester	40	7	53	0	0	162
Stonehill Col	47	6	41	2	4	168
Suffolk Univ	58	5	31	3	3	88
Tufts Univ	52	9	31	5	3	78
Univ of Mass	39	7	51	2	1	310
Wellesley College	56	4	21	3	16	74
Wentworth Institute	30	5	61	0	4	494
Western New England Col	47	6	37	1	9	212
Wheaton Col	56	10	28	3	3	118
Williams Col	50	3	38	5	4	65
Worcester Jr Col	67	4	29	0	0	130
Worcester Poly Inst	46	5	41	2	6	177
Averages	52	7	29	3	9	88
NEW HAMPSHIRE						
Colby Jr Col for Women	63	4	27	4	2	112
Dartmouth Col	57	5	29	3	6	78
Keene St Col	51	5	38	1	5	121
Mount St Mary Col	43	26	23	1	7	72
New England Col	90	10	0	0	0	54
Notre Dame Col	66	3	30	1	0	53
Plymouth St Col	42	5	50	0	3	136
Queen of Peace Missn Sem	33	0	42	0	25	655

Percentage of total operating expenditures						Annual
			Books			Expenditures
			and			in cents
State & Institution	Salaries	Wages	Materials	Binding	Other	per volume
NEW HAMPSHIRE continued						
Rivier Col	59	10	28	2	1	56
St Anselms Col	31	7	54	6	2	111
Univ of New Hampshire	49	7	33	4	7	110
Averages	53	6	32	3	6	93
RHODE ISLAND						
Barrington Col	50	9	36	2	3	49
Brown Univ	58	7	25	4	6	76
Catholic Teach Col	82	0	18	0	0	194
Providence Col	65	7	25	2	1	62
Rhode Island Col	48	3	45	2	2	229
R I School of Design	66	3	25	1	5	134
Roger Williams Jr Col	76	0	22	0	2	253
Salve Regina Col	62	1	30	1	6	91
Sem of Our Lady of Prov	86	0	9	2	3	152
Univ of Rhode Island	36	5	49	5	5	119
Averages	54	6	32	3	5	90
VERMONT						
Bennington Col	56	8	30	4	2	99
Castleton St Col	48	11	41	0	0	134
Johnson St Col	61	9	3	0	27	136
Lyndon St Col	55	10	33	0	2	116
Marlboro Col	46	24	25	2	3	107
Middlebury Col	58	6	30	2	4	67
Norwich Univ	54	3	29	4	10	68
St Michaels Col	51	7	35	2	5	74
Univ of Vt & St Agric Col	52	8	33	4	3	132
Vermont Col	63	12	19	4	2	102
Vermont Tech Col	67	0	26	0	7	205
Averages	54	7	32	3	4	103

State and institution	Number of inter-library loan trans-actions	Hours per week library was open	Library classi-fication (see head-note)	Personnel having faculty status (see head-note)	Expenditure ratios (See Intro. for explanation of numerators and denominators)		
					Dollar per FTE student	Dollar per FTE faculty member	Library expendi-ture index (in percent)
CONNECTICUT							
ALBERTUS MAGNUS COLLEGE		63	DC	CH	51	663	4.6
ANNHURST COLLEGE	22	56	DC	SE	93	978	
BRIDGEPORT ENGR INSTITUTE		12	DC	SE	9		
CENTRAL CONN STATE COL	270	77	DC	SE	45	1,447	8.3
CONNECTICUT COLLEGE	302	95	DC	CH	94	1,201	5.8
DANBURY STATE COLLEGE	40	68	DC	CH	51	1,013	6.5
FAIRFIELD UNIVERSITY	57	76	LC	AL	39	946	4.6
HARTFORD SEM FOUNDATION	211	66	OTH	CH	268	1,680	9.4
HARTFORD ST TECH INST	8	32	DC	CH	23		5.3
HOLY APOSTLES SEMINARY	70	90	LC	NO	168	2,707	10.9
MITCHELL COLLEGE		75	DC	CH	34	1,045	5.1
MT SACRED HEART COLLEGE	325	40	DC	CH	253	2,783	
NEW HAVEN COLLEGE		74	DC	AL	23	591	3.9
NORWALK COMMUNITY COL		52	DC	SE	34	1,250	7.2
QUINNIPIAC COLLEGE	25	52	DC	SE	31	679	5.2
ST BASILS COLLEGE		40	DC	AL	273	869	
ST JOSEPH COLLEGE	29	79	DC	SE	56	876	4.5
ST THOMAS SEMINARY	27	67	DC	CH	79	1,139	
SEAT OF WISDOM COLLEGE	50	120	DC	CH	132	1,233	18.5
SOUTHERN CONN STATE COL	96	74	OTH	AL	41	1,024	
TRINITY COLLEGE	658	84	DC	SE	101	1,279	5.7
UNIVERSITY OF BRIDGEPORT	118	72	DC	NO	23	533	3.3
UNIVERSITY OF CONNECTICUT	2,344	89	DC	CH	65	697	4.1
WESLEYAN UNIVERSITY	735	88	COM	SE	224	1,560	5.4
WILLIMANTIC STATE COLLEGE	35	61	DC	CH	82	2,365	7.2
YALE UNIVERSITY	6,914	97	LC	AL	308	1,769	5.6
MAINE							
AROOSTOOK ST TEACHERS COL		63	DC	AL	62	1,371	
BANGOR THEOLOGICAL SEM	6	72	DC	CH	176	1,399	8.8
BATES COLLEGE	176	72	DC	CH	73	1,163	5.0
BLISS COLLEGE	25	10	LC	CH	24		4.6
BOWDOIN COLLEGE	427	94	COM	SE	221	1,847	6.0
COLBY COLLEGE	173	84	LC	SE	70	861	4.3
FARMINGTON ST TEACHRS COL	275	63	OTH	AL	49	858	3.3
FT KENT STATE TEACHRS COL		49	LC	NO	48	569	3.6
GORHAM STATE TEACHERS COL	3	63	DC	SE	47	1,063	
HUSSON COLLEGE	50	60	DC	NO	17	383	
NASSON COLLEGE	28	81	DC	AL	92	1,306	7.8
OBLATE COLLEGE & SEMINARY		56	DC	CH	198	1,088	
ST FRANCIS COLLEGE	11	59	DC	CH	90	811	8.6
ST JOSEPHS COLLEGE			DC	CH	49	539	5.5
UNIVERSITY OF MAINE 5/	887	96	DC	AL	38	568	2.2
WASHINGTON ST TEACHRS COL	200	80	DC	CH	39	1,020	3.6
MASSACHUSETTS							
AMERICAN INTERNATL COL	27	78	LC	AL	29	1,156	3.6
AMHERST COLLEGE	3,602	85	DC	SE	189	1,466	5.0
ANDOVER NEWTON THEOL SCH	8	73	OTH	CH	153	211	6.6
ANNA MARIA COL FOR WOMEN	2	68	DC	CH	39	604	8.6
ASSUMPTION COLLEGE	95	93	DC	NO			
ATLANTIC UNION COLLEGE	15	63	DC	NO	72	1,006	7.0
BABSON INST OF BUS ADMIN	9	83	COM	CH	51	1,346	3.3
BECKER JR COLLEGE		51	DC	CH	20		
BENTLEY COLLEGE ACC & FIN	9	74	DC	SE	24	1,175	4.6
BERKSHIRE CHRISTIAN COL	4	61	DC	AL	126	885	8.8
BOSTON COLLEGE	762	81	LC	AL	59	744	4.6
BOSTON UNIVERSITY	6,129	94	LC	NO	36	423	3.1
BRADFORD JR COLLEGE		87	DC	AL	83	803	3.6
BRANDEIS UNIVERSITY	673	100	LC	SE	256	1,194	4.5
CAPE COD COMMUNITY COL	30	52	DC	SE	29	548	6.6

State and institution	Number of inter-library loan trans-actions	Hours per week library was open	Library classi-fication (see head-note)	Personnel having faculty status (see head-note)	Expenditure ratios (See Intro. for explanation of numerators and denominators)		
					Dollar per FTE student	Dollar per FTE faculty member	Library expendi-ture index (in percent)
MASSACHUSETTS	CONT						
CARDINAL CUSHING COLLEGE		63	LC	AL	68	703	5.5
CLARK UNIVERSITY	2,523	85	COM	CH	60	697	2.7
COL OF THE HOLY CROSS	305	82	LC	CH	65	714	3.0
COL OF OUR LADY OF ELMS	2	70	COM	CH	39	812	7.8
DEAN JR COLLEGE	1	84	DC	AL	52	873	
EASTERN NAZARENE COLLEGE		78	OTH	NO	52	823	5.4
ELIOT-PEARSON SCHOOL	3	44	DC	CH	33	625	2.5
EMERSON COLLEGE	29	65	DC	CH	45	475	
EMMANUEL COLLEGE	6	95	COM	AL	43	457	5.0
EPISCOPAL THEOL SCHOOL	17	62	OTH	NO	138	1,014	4.9
FISHER JUNIOR COLLEGE		71	DC	CH	31	644	3.5
FRANKLIN INST OF BOSTON		55	DC	CH	20		
GARLAND JR COLLEGE	2	53	DC	CH	57	682	4.9
HARVARD UNIVERSITY	17,594	75	OTH	AL	440	1,362	
LASELL JR COLLEGE		80	DC	AL	40	588	2.3
LESLEY COLLEGE	5	70	COM	AL	66	1,099	4.7
LOWELL TECHNOLOGICAL INST	157	82	DC	CH	25	487	3.7
MARIST COLLEGE & SEMINARY	13	98	DC	CH	154	907	9.1
MASS BAY COMMUNITY COL	40	40	DC	CH	34	677	6.3
MASSACHUSETTS COL OF ART		39	DC	AL	94	1,470	11.5
MASS COL OF OPTOMETRY		35	OTH	NO	35	210	4.0
MASS COL OF PHARMACY	278	43	OTH	CH	40	516	4.9
MASS INST OF TECHNOLOGY	3,988	98	LC	SE	121	205	.6
MERRIMACK COLLEGE	24	81	LC	AL	26	478	2.7
MOUNT ALVERNIA COLLEGE	97		OTH	SE	165	1,100	24.8
MOUNT HOLYOKE COLLEGE	1,964	79	OTH	AL	90	1,013	4.1
NEW BEDFORD INST TECH	38	48	LC	CH	31	436	4.9
NFW ENG CONS OF MUSIC	41	58	COM	NO	70	245	3.0
NEWTON COL SACRED HEART	175	82	COM	AL	91	1,232	5.5
NEWTON JR COLLEGE		49	DC	AL	32	544	3.8
NICHOLS COL OF BUS ADM	4	74	DC	CH	25	426	2.4
NORTHEASTERN UNIVERSITY	220		DC	AL	15	382	2.4
NORTHERN ESSEX CMTY COL	17	45	DC	CH	38	674	8.0
PINE MANOR JR COLLEGE	24	68	DC	AL	52	573	3.0
QUEEN APOSTLES COL & SEM	1,767	84	DC	CH	437	1,006	19.3
RADCLIFFE COLLEGE	41	93	DC	NO	98		3.2
REGIONL CMTY COL GREENFLD	4	50	DC	CH	38	549	6.6
REGIS COLLEGE	39	69	DC	AL	57	604	4.5
ST HYACINTH COL & SEM		34	DC	NO	230	1,526	6.7
ST STEPHENS COLLEGE	150	[1]84	DC	CH			
SIMMONS COLLEGE	94	103	COM	NO	50	656	2.4
SMITH COLLEGE	4,048	92	DC	CH	137	1,225	5.2
SPRINGFIELD COLLEGE	253	87	COM	AL	52	829	3.4
STATE COL AT BOSTON		60	DC	NO	12	374.	
STATE COL AT BRIDGEWATER	23	72	DC	NO	23		5.9
STATE COL AT FITCHBURG	17	69	DC	CH	53	1,058	5.7
STATE COL AT FRAMINGHAM	50	64	LC	AL	30	639	5.9
STATE COL AT LOWELL		61	DC	CH	79	1,321	10.4
STATE COL AT NORTH ADAMS	8	52	DC	CH	52	1,345	10.6
STATE COL AT SALEM		42	DC	SE	32	920	8.1
STATE COL AT WESTFIELD	107	61	DC	NO	59	1,305	
STATE COL AT WORCESTER	144	55	DC	AL	50	1,128	9.8
STONEHILL COLLEGE	675	76	LC	SE	65	1,230	7.9
SUFFOLK UNIVERSITY	30		LC	CH	28	721	4.5
TUFTS UNIVERSITY	2,426	96	LC	SE	60	518	2.1
UNIV OF MASSACHUSETTS	4,050	87	LC	AL	104	1,284	3.1
WELLESLEY COLLEGE	589	77	DC	SE	159	1,780	6.0
WENTWORTH INSTITUTE	2	61	DC	SE	26	418	1.8
WESTERN NEW ENGLAND COL	5	60	DC	NO	25	694	4.1
WHEATON COLLEGE	175	91	DC	CH	152	1,690	6.0
WILLIAMS COLLEGE	729	83	LC	SE	145	1,128	4.3
WORCESTER JR COLLEGE		63	DC	NO	9	301	2.0
WORCESTER POLY INSTITUTE	392	70	DC	SE	69	646	2.8

State and institution	Number of inter-library loan trans-actions	Hours per week library was open	Library classi-fication (see head-note)	Personnel having faculty status (see head-note)	Expenditure ratios (See Intro. for explanation of numerators and denominators)		
					Dollar per FTE student	Dollar per FTE faculty member	Library expendi-ture index (in percent)
NEW HAMPSHIRE							
COLBY JR COL FOR WOMEN	279		DC	AL	66	80	5.0
DARTMOUTH COLLEGE	3,740	87	COM	SE	200	1,907	5.3
KEENE STATE COLLEGE	217	64	DC	AL	42	1,038	4.2
MOUNT ST MARY COLLEGE	9	66	DC	CH	57	483	3.3
NEW ENGLAND COLLEGE	157	61	OTH	CH	24	383	
NOTRE DAME COLLEGE	40	46	DC	CH	30	847	
PLYMOUTH STATE COLLEGE	162	58	DC	SE	39	1,040	2.8
QUEEN OF PEACE MISSN SEM		112	DC	CH	986	7,200	
RIVIER COLLEGE	122	70	DC	CH	46	842	7.5
ST ANSELMS COLLEGE	275	82	DC	CH	44	618	3.7
UNIV OF NEW HAMPSHIRE	1,177	98	DC	AL	70	818	4.0
RHODE ISLAND							
BARRINGTON COLLEGE	7	76	DC	CH	35	385	2.6
BROWN UNIVERSITY	3,991	101	LC	SE	184	955	5.6
CATHOLIC TEACHERS COLLEGE		40	DC	CH	28	601	
PROVIDENCE COLLEGE	17	80	DC	CH	14	224	1.0
RHODE ISLAND COLLEGE	87	85	DC	AL	49	883	4.5
R I SCHOOL OF DESIGN	14	64	DC	CH	50	450	2.5
ROGER WILLIAMS JR COL		42	OTH	AL	15	270	6.1
SALVE REGINA COLLEGE		57	DC	CH	50	501	6.2
SEM OF OUR LADY OF PROV		70	COM	CH	174	1,177	15.5
UNIV OF RHODE ISLAND	1,165	92	DC	CH	42	650	2.8
VERMONT							
BENNINGTON COLLEGE	173	84	DC	AL	119	847	4.3
CASTLETON STATE COLLEGE	75	70	DC	CH	39	596	3.8
JOHNSON STATE COLLEGE	60	69	DC	CH	59	967	6.6
LYNDON STATE COLLEGE	214	73	DC	CH	58	801	3.6
MARLBORO COLLEGE	110	168	DC	CH	112	590	4.6
MIDDLEBURY COLLEGE	245	89	DC	CH	74	874	3.6
NORWICH UNIVERSITY	301	84	DC	CH	13	622	4.7
ST MICHAELS COLLEGE	155	66	LC	SE	37	664	3.3
UNIV OF VT & ST AGRIC COL	1,830	94	CC	NO	97	858	
VERMONT COLLEGE	4	34	DC	CH	25	330	1.6
VERMONT TECH COLLEGE		50	DC	AL	33		2.3

Summary of College and University Library Statistics: Aggregate United States, 1959-64

(Figures are rounded at levels appropriate to the precision of the data)

Item	1959-60	1960-61	1961-62	1962 63	1963 64
Number of libraries	1,951	1,975	1,985	2,075	2,140
Number of students served (enrollment)	3,400,000	3,600,000	3,900,000	4,300,000	4,800,000
COLLECTIONS					
Number of volumes at end of year	176,700,000	189,100,000	201,400,000	215,000,000	227,100,000
Number of volumes per student	51.9	52.4	51.6	49.4	47.3
Number of volumes added during year	8,400,000	9,400,000	10,900,000	12,300,000	13,600,000
Number of volumes added per student	2.5	2.6	2.8	2.8	2.8
Number of periodicals received	1,300,000	1,400,000	1,500,000	1,600,000	1,800,000
Number of periodicals per student	0.4	0.4	0.4	0.4	0.4
PERSONNEL					
All personnel (in full-time equivalents, excluding maintenance staff)	18,000	19,500	21,100	23,300	25,200
Professional personnel	9,000	9,700	10,300	11,200	11,900
Professional personnel as a percentage of total staff	50	50	49	48	47
Nonprofessional personnel	9,000	9,800	10,800	12,100	13,300
Nonprofessional personnel as a percentage of staff	50	50	51	52	53
Ratio of professional staff to students	1:378	1:372	1:378	1:388	1:401
Number of hours of student assistance	12,100,000	13,200,000	14,200,000	14,500,000	16,400,000
OPERATING EXPENDITURES					
Total operating expenditures (excludes capital outlay)	$137,200,000	$158,900,000	$183,900,000	$213,000,000	$246,700,000
Operating expenditures per student	$40.34	$44.02	$47.10	$50.95	$51.25
Operating expenditures as a percentage of educational and general expenditures	3.0	3.1	3.1	3.2	3.3
Salaries (all personnel not on hourly rates)	$72,500,000	$83,800,000	$95,900,000	$113,000,000	$126,200,000
Salaries as a percentage of operating expenditures	52.8	52.7	52.2	53.1	51.2
Wages (at hourly rates of pay)	$11,700,000	$13,900,000	$15,500,000	$17,000,000	$19,000,000
Wages as a percentage of operating expenditures	8.5	8.7	8.4	8.0	7.7
Expenditures for books and library materials	$40,800,000	$48,300,000	$56,400,000	$65,000,000	$80,500,000
Such expenditures as a percentage of operating expenditures	29.7	30.4	30.7	30.5	32.1
Expenditures for binding	$4,900,000	$5,000,000	$6,200,000	$7,000,000	$7,900,000
Such expenditures as a percentage of operating expenditures	3.6	3.2	3.4	3.3	3.7
Other operating expenditures	$7,500,000	$7,900,000	$9,700,000	$11,000,000	$13,100,000
Other operating expenditures as a percentage of operating expenditures	5.4	5.0	5.3	4.2	5.3

APPENDIX 4

Brevity Codes

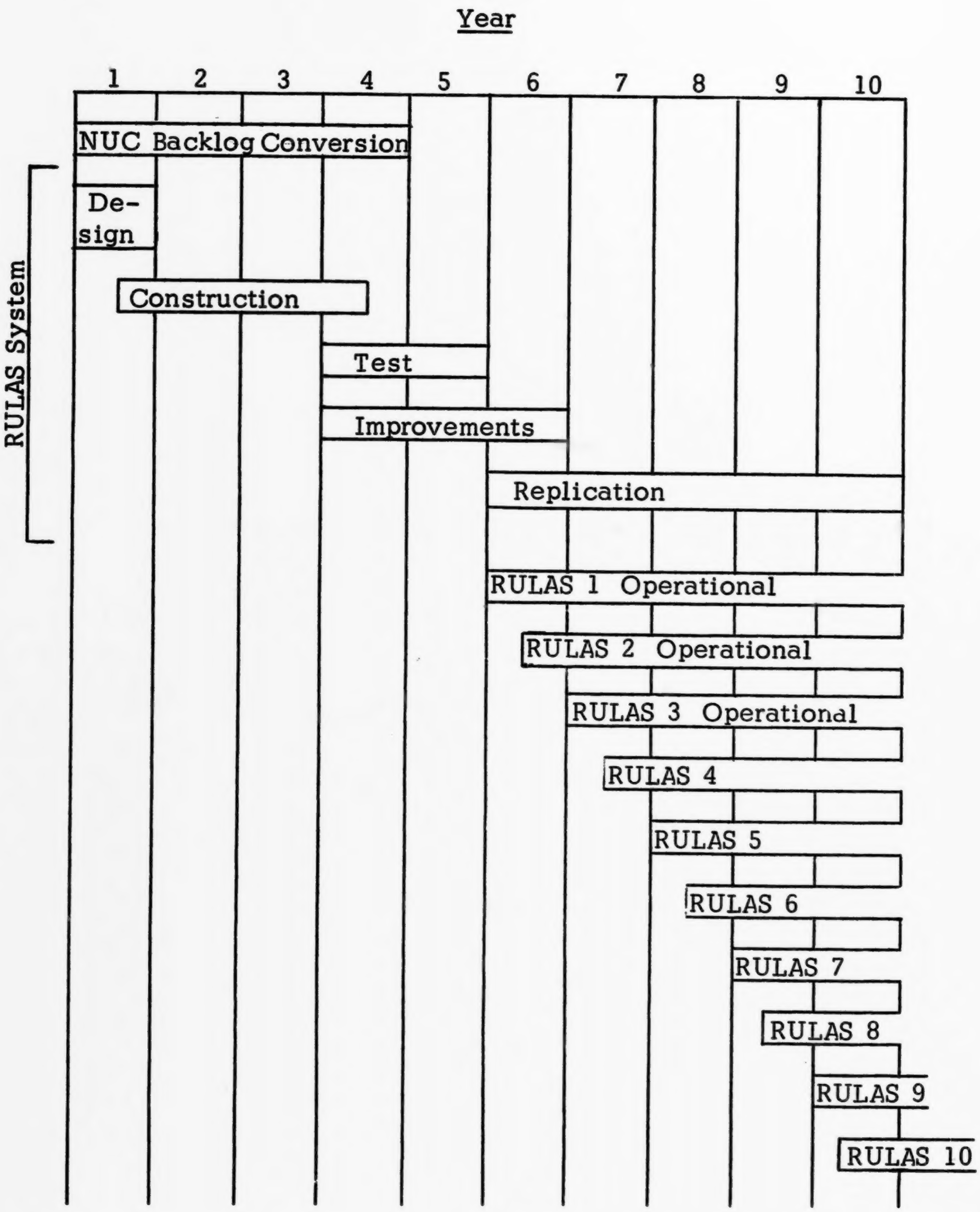
A brevity code is a table relating highly redundant representations to minimally redundant ones. Given either representation, reference to the table produces the other.

Five characters are more than adequate to provide a non-redundant, unique identifier to every individual in the world. The customary coding of author names, however, averages five times the minimal number. Thus, if an author has written N works, customary coding requires about 25 x N characters; a brevity code uses 30 characters for the table and only 5 for each work (30+5xN). Brevity coding, therefore, is more efficient for every value of N greater than one. For N=2, for example, the saving is 20%; it's 50% for N=4 and approaches 80% as N becomes very large. Since, in searching for a name, the computer can examine the code first and, upon failing to find the name, search for it in the uncoded portion of the file, brevity coding need only be used when it actually provides a storage saving. In the absence of data on the average number of works per author, it is impossible to compute the saving due to coding. A reasonable estimate, however, would be about 25%.

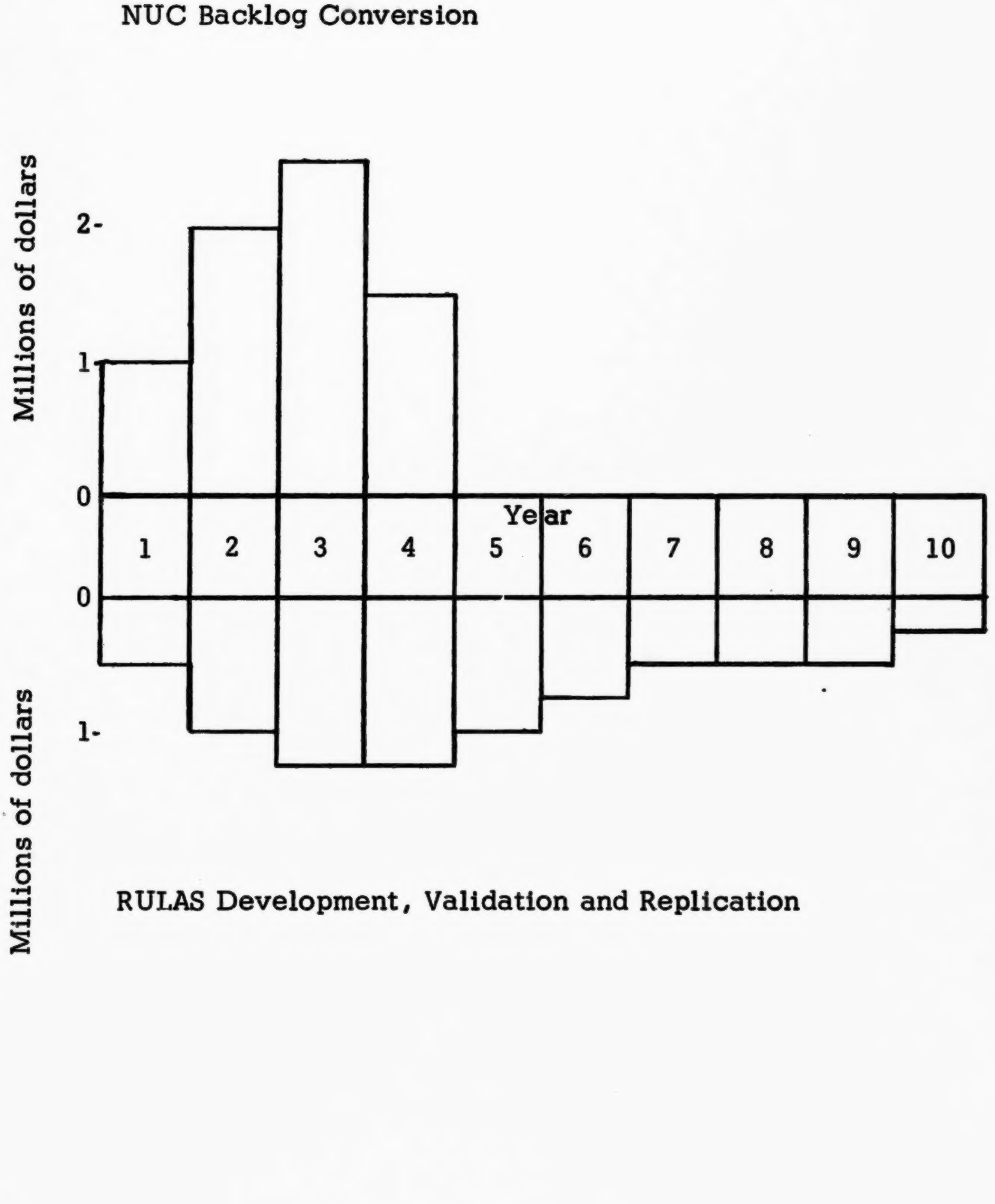
The savings will be even greater in using brevity codes for publisher and place of publication. The length of these names is about the same as the length of author names, while the minimal coding is about half that required for authors and the values of N are much larger. The probable storage saving is near 50%.

APPENDIX 5

Schedule for Constructing a National System



Estimated Expenditures for a National System



APPENDIX 6

Estimated Costs Per Item

Conversion into and Storage in Machine Readable Form

Item	Pages	Characters	Cost per item*	
			Conversion	Storage
Catalog card	$2x10^{-1}$	$5x10^{2}$	\$ $5x10^{-1}$	\$ $5x10^{-4}$
Table of contents	$2x10^{0}$	$5x10^{3}$	$5x10^{0}$	$5x10^{-3}$
Index	$2x10^{1}$	$5x10^{4}$	$5x10^{1}$	$5x10^{-2}$
Full Text	$2x10^{2}$	$5x10^{5}$	$5x10^{2}$	$5x10^{-1}$

* Conversion cost estimated at \$$10^{-3}$ per character.
Storage cost estimated at \$$10^{-6}$ per character.

...Library
. Chapter VIII

Estimated Costs Per Library

Conversion into and Storage in Machine Readable Form

Library	Volumes	Catalog Cards		Table of contents		Index		Full text	
		Conversion	Storage	Conversion	Storage	Conversion	Storage	Conversion	Storage
Small	$5x10^{3}$	$\$2x10^{3}$	$\$2x10^{0}$	$\$2x10^{4}$	$\$2x10^{1}$	$\$2x10^{5}$	$\$2x10^{2}$	$\$2x10^{6}$	$\$2x10^{3}$
Medium	$5x10^{4}$	$2x10^{4}$	$2x10^{1}$	$2x10^{5}$	$2x10^{2}$	$2x10^{6}$	$2x10^{3}$	$2x10^{7}$	$2x10^{4}$
Large	$5x10^{5}$	$2x10^{5}$	$2x10^{2}$	$2x10^{6}$	$2x10^{3}$	$2x10^{7}$	$2x10^{4}$	$2x10^{8}$	$2x10^{5}$
Very Large	$5x10^{6}$	$2x10^{6}$	$2x10^{3}$	$2x10^{7}$	$2x10^{4}$	$2x10^{8}$	$2x10^{5}$	$2x10^{9}$	$2x10^{6}$
All recorded knowledge	$5x10^{8}$	$2x10^{8}$	$2x10^{5}$	$2x10^{9}$	$2x10^{6}$	$2x10^{10}$	$2x10^{7}$	$2x10^{11}$	$2x10^{8}$